

ANKLE FRACTURES

With special reference
to post-traumatic arthrosis

By
MATS BAUER

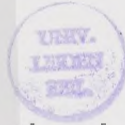


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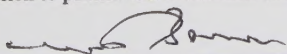
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Abstract From measurements on roentgen films of healthy and fractured ankles it was concluded that differences in joint space of the ankle are studied as well in films of non-weight bearing as in weight bearing ankle films and that joint space does not change with age in adult man. Ninety-two cases of ankle fractures randomized to closed reduction and plaster cast fixation or open reduction and osteosynthesis with the AO-method were compared with regard to function and arthrosis. The operated cases were better reduced, had less swelling and had faster gained in range of motion. Later - after on average 7 years - there was no longer any difference between the two treatment attitudes. One hundred and forty-three patients, conservatively treated with plaster cast fixation for ankle fracture were reviewed after on average 29 years. Most patients - 83% - were free of symptoms and in the remainder the symptoms were moderate, only a few had sought medical advice following their fracture. Eighty-two per cent were free of radiographic signs of arthrosis. One group, the supination-eversion injuries involving only the lateral malleolus, had arthrosis - minimal signs - in one patient only. It is concluded that the isolated supination eversion fracture of the lateral malleolus does not require operation and that residual symptoms following ankle fractures on the whole contribute but little to locomotor incapacity. In a comparison of the sex and age specific incidences of ankle fracture from the 1950's and the 1980's a considerable increase was found: The risk of stage IV supination-eversion fractures had increased, particularly in the elderly women.				
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Date July 12, 1985

ANKLE FRACTURES

With special reference to post-traumatic arthrosis

by

Mats Bauer
Leg.läk. Vg

Akademisk avhandling som med vederbörligt tillstånd av Medicinska Fakulteten vid Universitetet i Lund för avläggande av medicine doktorsexamen kommer att offentligen försvaras å Universitets-klinikernas aula, Allmänna Sjukhuset i Malmö, fredagen den 25/10 1985, kl. 14.00.

From the Departments of General Surgery, Orthopedic Surgery and Diagnostic Radiology, Östersund Hospital, and the Departments of Orthopedic Surgery and Diagnostic Radiology, Malmö General Hospital (Lund University), S-214 01 Malmö, Sweden.

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Second edition

To my family

This thesis is based on the following publications:

- I. ARTHROSIS ON THE ANKLE EVALUATED ON FILMS IN WEIGHT-BEARING POSITION.
M. Bauer, B. Bergström and A. Hemborg. Acta Radiol. Diagn. 20:88-92, 1979.
- II. WIDTH OF THE NORMAL ANKLE JOINT.
K. Jonsson, H.O. Fredin, C.G. Cederlund and M. Bauer. Acta Radiol. Diagn. 25:147-149, 1984.
- III. MALLEOLAR FRACTURES. NONOPERATIVE VERSUS OPERATIVE TREATMENT.
A controlled study.
M. Bauer, B. Bergström, A. Hemborg and J. Sandegård.
Accepted for publication in Clin. Orthop. No. 199, 1985.
- IV. THIRTY-YEAR FOLLOW-UP OF ANKLE FRACTURES.
M. Bauer, K. Jonsson and B. Nilsson
Acta Orthop. Scand. 56:103-106, 1985.
- V. SUPINATION-EVERSION FRACTURES OF THE ANKLE JOINT - CHANGES OVER 30 YEARS.
M. Bauer, U. Bengné, O. Johnell and I. Redlund-Johnell.
Submitted for publication in Foot & Ankle.

In the thesis the papers are referred to by their Roman numerals.

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INTRODUCTION

Fractures involving the ankle are the most common intra-articular fractures in a weight-bearing bone in man (Willenegger 1961, Lange et al. 1984, Phillips et al. 1985) and the most common of the fractures of the lower limb (Buhr & Cooke 1959). There is a vast literature on the subject, including suggestions for treatment. Evaluations of treatment have been hampered by the unfortunate fact that the natural course of ankle fractures is unknown.

Since post-fracture arthrosis (osteoarthritis) is an important variable in the assessment of the treatment of ankle fractures, also the effects of normal aging on the ankle joint must be known - such as the change with age of the joint width.

Only with such background data, meaningful comparisons between methods of treatment will be possible.

The importance of the trauma energy - the amount of energy absorbed by the tissues - is demonstrated by studies on tibia shaft fractures (Bauer et al. 1962, Edwards 1965, van der Linden et al. 1975). This is one reason why only strict randomization and a rigid protocol will - in the end - permit any conclusions (van der Linden 1980, Editorial, Lancet 1980).

Surgical randomized trials are scarce in surgery, but recently Phillips et al. (1985) presented a prospective randomized study on the management of severe ankle fractures.

Treatment of ankle fractures

Excellent reviews of historical time have been published by several authors (Ashurst & Bromer 1922, Lauge-Hansen 1942, Magnusson 1944, Bonnin 1950, Klossner 1962, Cedell 1967). A very extensive historical review was presented by Weber (1972).

Hippocrates (cited by Lauge-Hansen 1942) described dislocation of

the ankle in conjunction with fractures, Petit (1723) described ligamentous lesions in connection with malleolar fractures, and Pott (1769) a fracture of the distal end of the fibula associated with a lateral dislocation of the ankle and disruption of the deltoid ligament.

Cooper in 1822 pointed out that there were several types of ankle fractures including avulsions of the tibia margins.

Dupuytren (1836,1839) was the first to undertake experiments by producing ankle fractures in cadavers. It was suggested that forced ab- or adduction of the foot would cause fractures.

Maisonneuve (1840) thought that most fractures were caused by external rotation of the pronated foot. Quénu, (1906) on the other hand, suggested that external rotation of the supinated foot was the most common cause of ankle fractures.

Fractures of the posterior malleolus were described as early as 1828 by Earle, and fractures of the antero-lateral margin of the tibia, including the insertion of the anterior tibio-fibular ligament, by Tillaux (1872).

Von Volkmann in 1875 described fracture fragments from the anterior border of the tibia.

Hönigschmied (1877) focused interest on the combination of ligamentous lesions and fractures.

A ruptured syndesmosis and its surgical treatment was first described by Clermont (1913).

Henderson (1932) invented the term trimalleolar fracture for fractures involving the posterior lip of the tibia, which Destot in 1912 had named "the third malleolus". Fractures of the posterior lip were thoroughly investigated by Hendelberg (1943).

Even if a high percentage of failures were reported after closed reduction and plaster cast treatment, many well-known surgeons - Bonnin (1950), Böhler (1957), Charnley (1961) and Watson-Jones (1962) - still recommended the conservative treatment of almost every ankle fracture, and operative treatment was suggested only after failed attempts at closed reduction.

The era of operative treatment, however, began as early as 1875 with von Volkmann. Lane (1893, 1914) and Lambotte (1913) proposed operative treatment of ankle fractures. The further development of operative principles and technical devices has taken two directions.

One aims for a stable joint, permitting early movement of the operated ankle with no or only a short period of immobilization. This method was first introduced by Müller (1945) and Danis (1949) and further developed by the Swiss surgeons Müller, Allgöwer & Willenegger (1963) and Weber (1966) representing the AO-group. To achieve complete restoration of joint anatomy, sometimes extensive operative procedures are proposed, including plates and multiple screws.

The other operative school has the same goal, exact reconstruction of the ankle joint, but with the aid of only a few and small osteosynthesis devices - small staples, small pins and wires - just enough to keep the malleolar fragments adapted during consolidation in a plaster cast (Cedell & Wiberg 1962, Cedell 1967).

However, a third approach was presented by Vasli (1957), who after stable internal fixation started active movements very early post-operatively for one to three weeks, before the application of a plaster cast for the rest of the consolidation period.

High rates of non-union of the medial malleolus have been reported after conservative treatment (Magnusson 1944, Baek Kristensen 1949, Biström 1952, Klossner 1962, Burmeister 1963, Stören 1964, Sneppen 1970). For many years, most attention was paid to the medial aspect of the joint. Müller (1945) thought that exact



restoration of the medial structures was sufficient, disregarding the lateral lesions. Danis (1949) stressed the importance of a complete restoration of all damaged elements, especially a fractured fibula.

Vasli (1957) had 87 per cent good results from operative treatment of 187 cases with malleolar fractures - at that time an extraordinary result. In spite of good reduction he found, however, a high rate of post-traumatic arthrosis (43 per cent).

Many authors have since then reported better results after operative than after conservative treatment (Klossner 1962, Wilson & Skilbred 1966, Cedell 1967, Solonen & Lauttamus 1968, Hughes et al. 1979, Yde & Kristensen 1980b, Phillips et al. 1985).

Excellent results have also been reported by authors using operative treatment according to the AO-principles (Forudastan 1970, Willenegger 1971, Weber 1972, Pankarter 1977, Hughes et al. 1979, Mitchell et al. 1979, Lindsjö 1981).

A major problem, however, when discussing the outcome of different approaches to treatment, has been the absence of generally accepted methods of classifying the fractures, and reproducible criteria for the grading of results - subjective, clinical and roentgenological (Phillips & Spiegel 1979).

Classification of ankle fractures

In 1922 Ashurst & Bromer presented the first more generally accepted classification which was not only descriptive. According to the main vector of the trauma, the fractures were divided into those caused by external rotation, abduction fractures and adduction fractures. A fourth group was fractures caused by forces along the longitudinal axis of the lower leg (compression).

In 1942, after extensive cadaver experiments, Lauge-Hansen published his thesis with a "genetic" classification of ankle fractures. By provoking the ankle in various positions into

various directions, series of fractures with typical radiographic features were obtained. He assigned double names to each type, the first part defining the position of the foot, and the second describing the direction of the trauma.

Four major groups were described, supination-adduction fractures (SA), supination-eversion fractures (SE), pronation-abduction (PA) and pronation-eversion (PE), each with a number of subgroups.

Supination-adduction injuries

Stage one (SA I) is a lateral malleolar fracture below the level of the talo-crural joint or a lateral ligamentous injury.

In stage two (SA II) there is also a vertical fracture through the medial malleolus.

Supination-eversion injuries

The first stage (SE I) comprises an injury to the anterior tibiofibular ligament, either a bony avulsion from its proximal or distal attachments, or a rupture through the ligamentous substance.

In stage two (SE II) an oblique fracture in the lateral malleolus is added.

Stage three (SE III) injuries imply the addition of a fracture through the posterior tibia margin.

In stage four (SE IV), finally, the above injuries are accompanied by an avulsion fracture through the medial malleolus or a rupture of the deltoid ligament.

Pronation-abduction injuries

Pronation-abduction (PA) injuries start in stage one (PA I) with a short avulsion fracture through the medial malleolus.

In stage two (PA II) the attachment of the anterior tibiofibular ligament is severed and there might also be a fracture of the posterior tibia rim and, sometimes, a compression in the lateral

tibia joint surface.

In stage three (PA III) a short oblique fracture of the fibula, sometimes with a small lateral wedge, just above the talo-crural joint, appears.

Pronation-eversion injuries

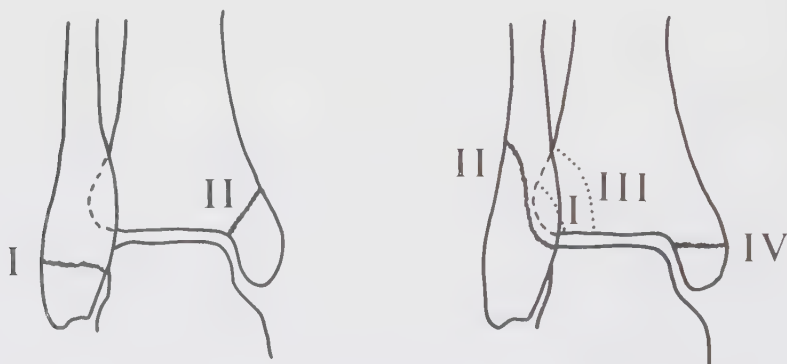
Pronation-eversion injuries (PE) feature in their first stage (PE I), an avulsion fracture of the medial malleolus.

In stage two (PE II) the anterior tibio-fibular ligament is injured.

In stage three (PE III) a torsional fracture of the fibula occurs well above the level of the talo-crural joint.

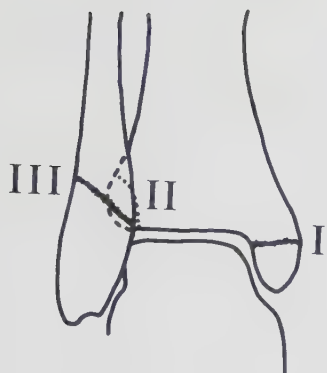
The fourth stage (PE IV) comprises the above injuries in combination with a fracture of the posterior tibia margin.

Classification according to Lauge-Hansen

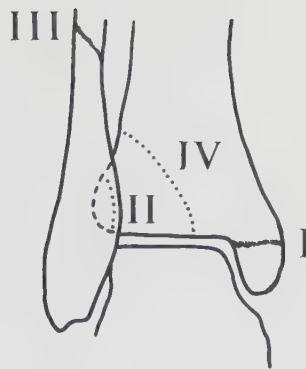


SA. Supination-adduction.

SE. Supination-eversion



PA. Pronation-abduction



PE. Pronation-eversion

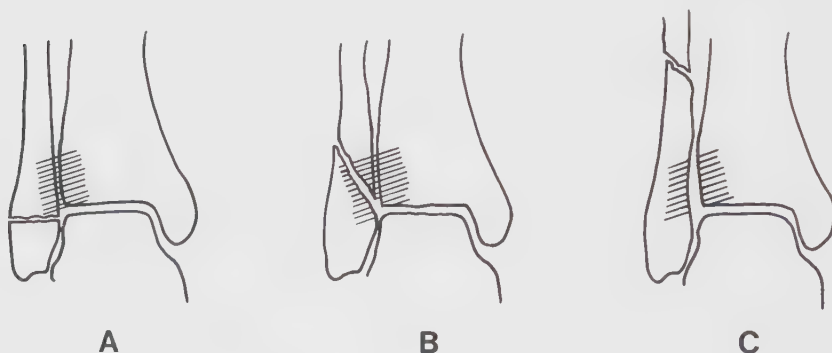
The injuries are believed to occur in this order and the stages should therefore represent a grading of the severity of the injury. Lauge-Hansen (1949) stated that there may be pure ligamentous injuries, instead of proper fractures in some stages, which makes the system more easily acceptable.

Pronation-dorsiflexion injuries

Lauge-Hansen in his thesis of 1942 also described two injuries with a fracture of the basis of the medial malleolus in combination with a large anterior tibia fragment incurred by falling from high levels. He could find no experimental explanation for this injury and believed it to be caused by forced dorsiflexion of a pronated foot in combination with compression of the joint. These injuries are not ankle fractures in their conventional sense but rather a type of the so-called pilon fractures.

In 1949 Danis described a classification which was later adopted and modified by Weber (1972). In this system dislocation fractures are divided into three groups A, B and C, depending on the level of the fibula fracture in relation to the talo-crural joint and the syndesmosis (Weber 1972, Lindsjö 1981).

Classification according to Danis-Weber



In fractures type A there is an injury to the lateral structures distal to the level of the talo-crural joint. It may occur as a bony injury - a transverse fibular fracture - or as a rupture of the anterior fibulo-talar and fibulo-calcaneal ligaments. On the medial side there may be an almost vertical fracture of the medial malleolus. The syndesmosis and the deltoid ligament are probably not injured, but a medial posterior tibial fragment may occur. The dominant trauma is believed to be a forced supination of the foot.

In fractures type B the lateral injury is an oblique fracture of the fibula at the level of the syndesmosis. This is in 50 per cent of the cases accompanied by a rupture of the syndesmosis (Weber 1972). According to Weber the dominant causing trauma is external

rotation. When the dislocation is severe there will be a fracture of the medial malleolus, usually transverse, or a rupture of the deltoid ligament as well. Fractures of the postero-lateral part of the tibia could also occur.

In fractures type C there is a fibula fracture above the syndesmosis, which is always associated with an injury to the syndesmosis. The fibula fracture may be a subcapital fracture of the Maisonneuve type (Maisonneuve 1840). In rare cases there is a purely ligamentous lesion with a widening of the ankle mortise, without any fibula fracture. In type C, the medial injuries comprise avulsion fractures of the medial malleolus or ruptures of the deltoid ligament. Sometimes a postero-lateral tibia fragment can be found. Weber proposes that these injuries are a combination of a forced external rotation and a component of compression.

This system has gained considerable popularity in Europe since it is the basis for operative planning according to the AO-principles (Müller et al. 1963, Weber 1972).

These classifications apply to adults only. For childrens' fractures special classifications have been presented (Salter & Harris 1963, Dias & Tachdijan 1978, Spiegel et al. 1978, Vahvanen & Aalto 1980, Landin & Danielsson 1983).

Combined fractures

Fractures in the distal end of the tibia shaft may occur in connection with ankle injuries. If the distal ends of both the tibia and the fibula are fractured, there is less risk of an injury to the syndesmosis (Lindsjö 1981).

Arthrosis of the ankle

Little is known about the appearance of the normal ankle joint in relation to age. The opinion prevails that the diagnosis of arthrosis of the ankle should be reserved for cases with a reduced joint space (Magnusson 1944, Cedell 1967, Matzen & Fleissner 1969, von Elmendorff et al. 1971, Bargon & Henkemayer 1977, Bargon 1978, Lindsjö 1981, Langenscheidt 1983).

Radiograms obtained in weight-bearing have been shown to be of value for establishing the diagnosis of arthrosis of the knee joint (Ahlbäck 1968). Whether this applies also to the ankle has so far not been investigated.

In the hip and knee joints the prevalence of arthrosis is a few per cent (Danielsson 1964, Jörring 1980, Danielsson & Hernborg 1970). Primary arthrosis of the ankle appears to be extremely rare (Funk 1976, Stauffer et al. 1977).

The delicate mechanism required to maintain normal function in a joint can be disturbed in many ways. Matthiass & Glupe (1966), Refior & Hackenbroch (1976) and Moschinski et al. (1983) pointed out the deleterious effects of immobilization on the joint cartilage. In animal experiments Dustmann et al. (1971) observed the negative consequences for the cartilage of hemarthrosis - in man hemarthrosis after ankle injuries did not cause arthrosis (Schedl et al. 1982).

Contusions and chondral fractures are other traumatic events affecting articular cartilage. As stated by Rüter (1978) only a systematic arthroscopic investigation of injured ankles without radiographic evidence of a bony injury, could tell us how often and to what extent this occurs in the ankle joint - no such data have been published. Cartilage injuries often coincide with ankle fractures, however, and may be a common cause of arthrosis and poor results (Felsenreich 1931, Renné & Meinhardt 1974, Farkas et al. 1975, Stadler et al. 1975, Beck et al. 1978, Hughes et al.

Apart from direct trauma to the chondral surfaces, malleolar fractures left to heal in a displaced position could lead to incongruence arthrosis (Ger: Inkongruenz-Arthrose) (Lewis & Graham 1940, Riede et al. 1971a). This implies abnormal mechanics and early wear of the talo-crural joint. This could also be the fate of the articular surface after a posterior tibia rim fragment healed in a displaced position.

Ligamentous dysfunction with recurrent subluxation could lead to arthrosis (Rüter 1978, Harrington 1979) and so could "Verstarrungs Arthrose", a post-traumatic stiffness of the syndesmosis (Weber 1972).

Secondary arthrosis of the ankle also occurs following talar necrosis, infections and inflammatory disease (RA, gout) (Rüter 1978, Cotta & Puhl 1978, Kinzl 1983).

In spite of the great number of ankle fractures, post-traumatic arthrosis, severe enough to merit further treatment, such as an arthrodesis, remains rare, except after certain types of fractures affecting the ankle, notably the so-called impact fractures (pilon fractures) (Rüter & Burri 1978). These fractures are usually the result of direct violence or compression, which may cause severely comminuted fractures at the distal end of the tibia, the fibula and/or the talus.

Post-traumatic arthrosis of the ankle has been reported to develop soon after the fracture - usually within the first 1 - 1 1/2 years (Willenegger 1961, Cedell 1967, Rüedi & Allgöwer 1969, Bargon & Henkemeyer 1977, Lindsjö 1981).

Even if most investigators agree that residual displacement may cause post-traumatic arthrosis (Magnusson 1944, Bonnin 1950, Vasli 1957, Willenegger 1961, Burwell & Charnley 1965, Cedell 1967, Weber 1972) there is no consensus about the degree of displacement permissible - most authors use their own criteria (Baek Kristensen 1953, Cedell 1967, Weber 1972).

The presence of a posterior tibia fragment has been considered to be related to a poor end result (Felsenreich 1931, Hendelberg 1943, Willenegger 1961, Klossner 1962, Cedell 1967, Tauber et al. 1971, McDaniel & Wilson 1977). It has been proposed, however, that the presence of a posterior fragment may merely reflect the severity of the original injury. Niethard & Plaue (1977) found, that the prognosis was not significantly altered whether the posterior fragment was exactly reduced or not.

Classification of arthrosis of the ankle

Reduction of the joint space is an accepted criterion of arthrosis (Magnusson 1944, Cedell 1967, Matzen & Fleissner 1969, von Elmen-dorff et al. 1971, Bargon & Henkemeyer 1977, Lindsjö 1981, Langenscheidt 1983).

Several classifications have been published, and some will be presented here.

The classification of Magnusson (1944) which was later adopted by Cedell (1967):

<u>Degree</u>	<u>Roentgenological changes in the joint</u>
(+)	Slight reduction of the joint space and slight formation of deposits on the joint margins.
+	More pronounced changes than mentioned above, possibly with the addition of a sclerotic configuration within the subchondral osseous tissue of the tibia.
++	The joint space only about half as high as that of the uninjured side and rather pronounced formation of deposits.
+++	The joint space has quite or almost disappeared.

In the following studies the Magnusson-Cedell classification was applied and interpreted as illustrated in Figures 1 - 5. In the prospective study (III) the numbers 1 - 4 have been used for the same entities (compare Figures 1 - 5).

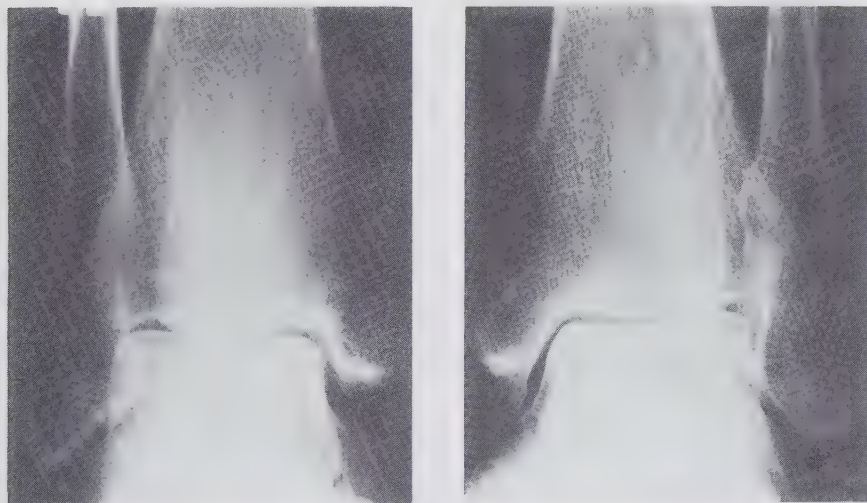


Figure 1. Obvious post-fracture changes but no arthrosis (fractured ankle to the right) (III = 0).

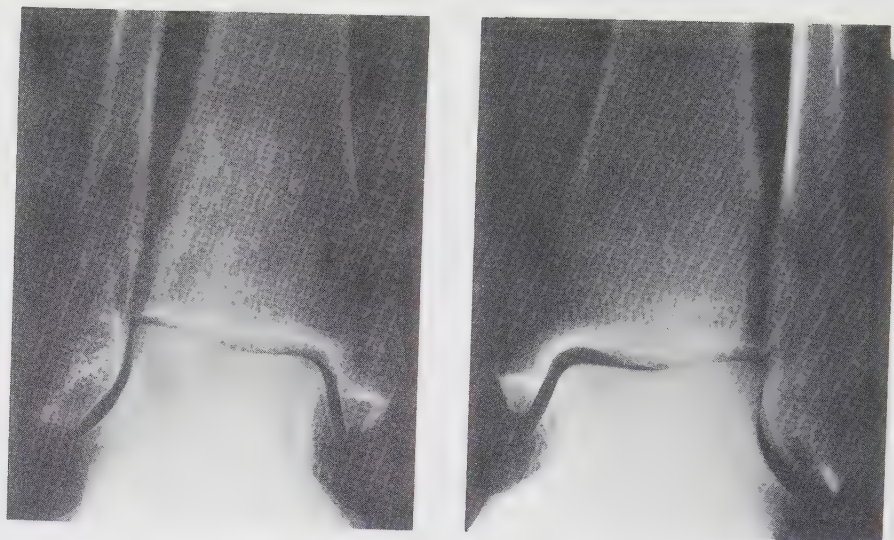


Figure 2. Arthrosis degree (+) (fractured ankle to the left) (III = 1).

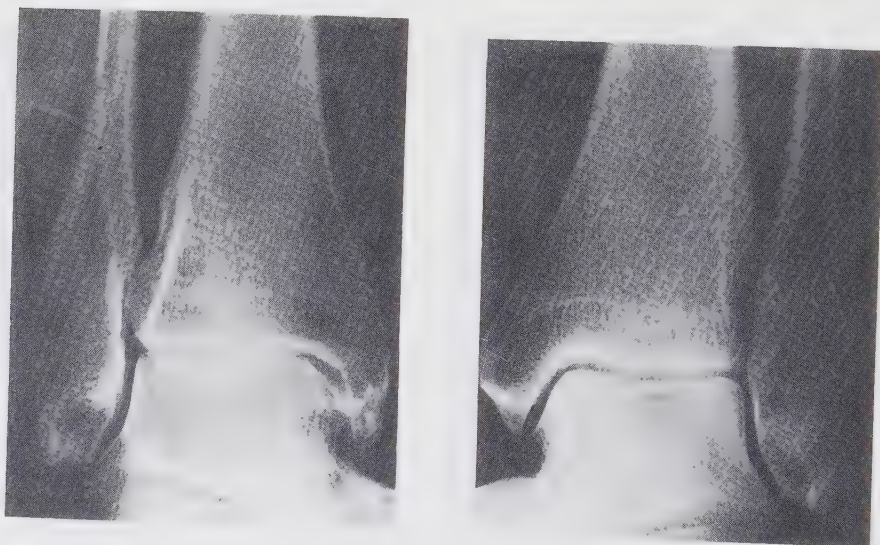


Figure 3. Arthrosis degree + (III = 2).

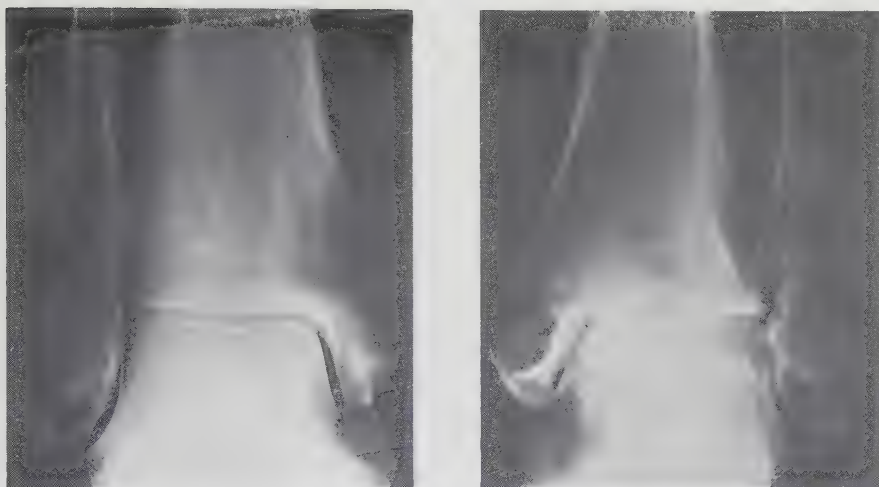


Figure 4. Arthrosis degree ++ (III = 3).

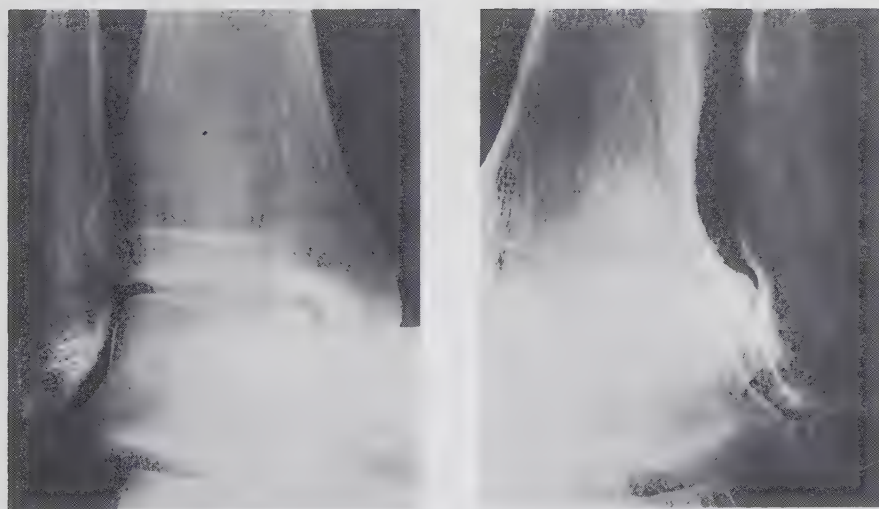


Figure 5. Arthrosis degree +++ (III = 4).

Bargon (1978) suggests the following classification:

<u>Degree</u>	<u>Roentgenological changes in the joint</u>
0	Sclerosis in the weight-bearing zone without reduction of joint width.
1	Sclerosis in the weight-bearing zone with marginal deposits. Slight reduction of joint width.
2	Sclerosis in the weight-bearing zone, osteophytes. Reduction of joint width. A tendency to fragmentation of the subchondral bone lamellae.
3	Reduction of the joint width, defects in the subchondral bone lamellae, cystic degeneration and sclerosis in the surrounding cancellous bone.

Bargon pointed out that none of his patients with arthrosis degree 0, when followed for up to 5 years, developed further signs of arthrosis and believed that a slight sclerosis in the weight-bearing zone is of no clinical or prognostic importance.

Weber (1972) had a different approach to the grading of late radiological results. He utilized the following grading system which is a combination of position and signs of degeneration.

Anatomically perfect without arthrosis	0
Anatomically perfect, slight calcification of ligament but no arthrosis	1
Anatomical incongruence only medially	2
Anatomical incongruence, laterally = arthrosis	3
Posterior step in the joint line = arthrosis. Dystrophy	4

Arthrosis is defined by Weber as a reduction of joint space and the formation of osteophytes.

Most authors, however, use their own systems. Von Elmendorff et al. (1971) divides arthrosis in the following two groups:

Light: Subchondral sclerosis

Slight reduction in joint width

Formation of joint deposits.

Marked: Marked reduction in joint width with progressive subchondral sclerosis and cystic degeneration in the bony structure.

The formation of loose bodies.

Marked osteophytosis.

Irregular joint surfaces with a "wavy" contour.

Von Elmendorff et al. in addition to this use the same criteria as Weber for the grading of late radiological results.

Lindsjö (1981) presented the following classification:

Arthrosis degree I: Slight diminution of the joint space compared with the uninjured ankle.

II: Narrowing of the joint space to half or less compared with the uninjured ankle.

III: The joint space almost eliminated and seen only as a very thin line on the radiograph.

Purpose of the investigations

The aims of the present study were:

To assess the value of films obtained in the weight-bearing position for the diagnosis of arthrosis.

To determine the normal ankle joint width in relation to age and sex.

To study factors influencing the outcome of ankle fractures - a therapeutic trial.

To describe the natural course - 30 years - of ankle fractures.

To describe the sex and age specific incidence of ankle fractures and changes over the last 30 years of possible importance for their treatment.

PAPERS

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I

ARTHROSIS OF THE ANKLE EVALUATED ON
FILMS IN WEIGHT-BEARING POSITION

M. BAUER, B. BERGSTRÖM and A. HEMBORG

The value of films exposed in weight-bearing positions in the evaluation of arthrosis of the knee has been emphasized by AHLBÄCK (1968). No corresponding investigation of the ankle joint has been found in the literature. At follow-up examinations of patients treated for malleolar fractures such films were included.

Material and Methods

Repeat examination of 113 patients, 69 women and 44 men (mean age 43.6 years, women 43.6, men 43.5, range 16–77 years) was performed about 7 years after the date of fracture (mean 83.9 months, range 68–98 months). The fractures were classified as follows: Type A—Transverse fibular fracture distal to the syndesmosis; Type B—Oblique fibular fracture at the level of the syndesmosis with or without rupture of the tibiofibular ligament; Type C—Oblique fibular fracture proximal to the syndesmosis with rupture of the tibiofibular ligament (Fig. 1).

Both ankles were examined in all patients with a standardized technique: The patient supine, vertical beam direction and three views—straight a.p. (lateral margin of the foot 90° to the horizontal plane, a.p. with the limb medially rotated 20°, and a lateral view with the leg and foot laterally rotated 85°. If necessary further films were exposed to obtain the best possible demonstration of the joint surfaces. Reproducible angles were obtained by using the device described by BOLIN (1961).

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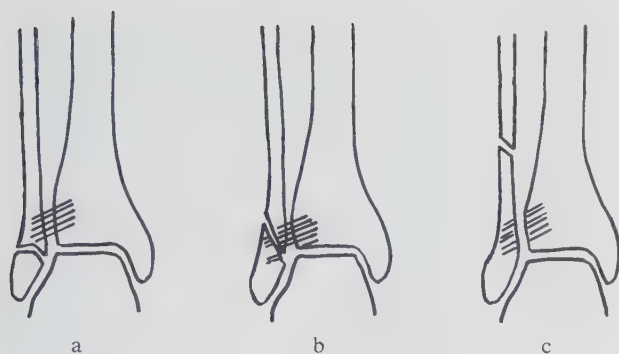


Fig. 1. Classification of fractures. a) Transverse fibular fracture distal to the syndesmosis (type A). b) Oblique fibular fracture at the level of the syndesmosis with or without rupture of the tibiofibular ligament (type B). c) Oblique fibular fracture proximal to the syndesmosis with rupture of the tibiofibular ligament (type C).

Table 1

Classification of arthrosis according to MAGNUSSON and CEDELL

Degree	Roentgenologic abnormality of the joint
(+)	Slight reduction of joint space and slight formation of osteophytes on joint margins
+	More marked abnormalities, possibly with addition of a sclerotic zone within subchondral osseous tissue of tibia
++	Joint space only about half as high as on uninjured side and rather marked formation of osteophytes
+++	Joint space has completely or almost disappeared

Table 2

Radiologic grading of arthrosis in 113 cases at the time of follow-up in relation to the initial type of fracture

Degree	Type of fracture		
	A	B	C
0	2	30	1
(+)	3	41	5
+	1	12	0
++	0	12	2
+++	0	4	0

In 110 of the 113 patients films in weight-bearing position could be obtained. The body weight was equally divided on both feet. One film was exposed with horizontal a.p. beam direction with the limb rotated 20° medially. When necessary, to obtain a clear view of the joint space between the talus and the lateral malleolus, further films in slightly altered projections were exposed. The same technique was applied

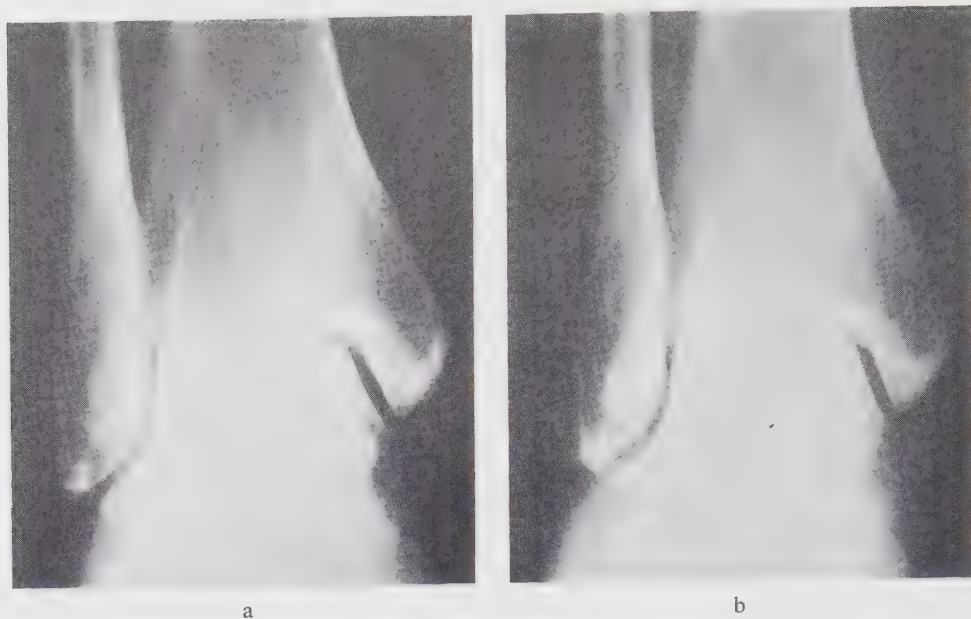


Fig. 2. a) Patient supine. b) View at weight-bearing. Arthrosis classified as + at both examinations.

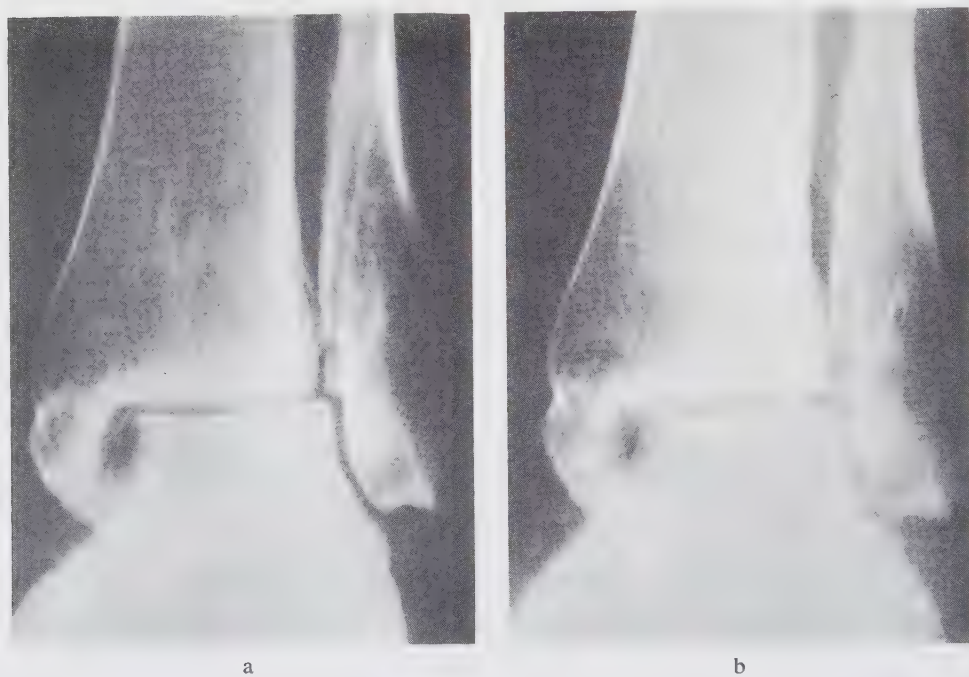


Fig. 3. a) Patient supine. Arthrosis classified as +. b) View at weight-bearing. Arthrosis classified as ++.

in 24 patients initially treated at this hospital, but now living elsewhere and examined by the authors at radiology departments in the residential areas of the patients. The arthrosis was classified according to MAGNUSSON (1944) and CEDELL (1967) (Table 1).

Results

The degree of arthrosis in the different types of fracture at the time of follow-up is listed in Table 2. In only 2 of 220 ankle joints examined did films exposed in standing add to the information provided by the films with the patients in supine position. In both cases a slight reduction of the distance between the talus and the tibial surface could be measured at weight-bearing. In one case the same degree of arthrosis was present at both types of examination, in the other case + was re-classified to ++ on weight-bearing (Figs 2, 3).

Discussion

In slight arthrosis of the ankle joint a local narrowing of the joint space may be present, most often in the lateral aspect. In view of the arched form of the joint in the sagittal plane, any narrowing present in the anterior or posterior parts of the joint cannot be demonstrated by a.p. beam direction. This may explain why only two cases with more marked narrowing of the joint space were found at weight-bearing since no lateral films were exposed of the joints in standing position. Thus, additional projections, when necessary achieved by fluoroscopy, and tomography would most probably have added to the information. However, this would be too time-consuming for routine use and was therefore refrained from. Also, in cases of advanced arthrosis films in weight-bearing position did not demonstrate the abnormality of the joint space any better than did the conventional examination.

Conclusion. Contrary to what AHLBÄCK has stated to apply for the knee, films of the ankle joint in weight-bearing position do not give further information in relation to the amount of extra work and increased radiation dose.

SUMMARY

About 7 years after a malleolar fracture 113 patients were examined for development of arthrosis. The addition of films exposed in weight-bearing position with a.p. beam direction to views of the ankle joint exposed in supine position did not contribute to the diagnosis of arthrosis.

ZUSAMMENFASSUNG

Etwa 7 Jahre nach einer Knöchelfraktur wurden 113 Patienten hinsichtlich der Entwicklung einer Arthrose untersucht. Zusätzliche Filme in Belastungsposition mit einer a.p. Strahlenrichtung, um das in aufrechter Stellung exponierte Fussgelenk darzustellen, trug nicht zur Diagnose einer Arthrose bei.

RÉSUMÉ

Cent treize patients ont été examinés environ 7 ans après une fracture malléolaire externe pour rechercher l'apparition d'une arthrose. La comparaison de films pris en charge avec une direction antéro-postérieure du rayonnement et de radiographies de la cheville prises en décubitus ne contribue pas au diagnostic d'arthrose.

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II

WIDTH OF THE NORMAL ANKLE JOINT

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Most likely osteoarthritis is primarily a disease of the cartilage (DANIELSSON 1964, AHLBÄCK 1968) and may affect any joint.

In view of the importance of a correct early diagnosis of osteoarthritis, it is essential to investigate the normal variation of the width of the joint space, as for instance has been made as regards the hip joint (FREDENSBORG & NILSSON 1978).

Osteoarthritis of the ankle is less common than in the hip and knee joints, and may be treated by surgery (AHLBERG & HENRICSON 1981, MORRIS & HERRICK 1976, HARRINGTON 1979, NEWTON 1982).

To our knowledge, there has been no systematic analysis of the normal space of the talocrural joint. The purpose of this investigation was to describe the joint space in the antero-posterior (a.p.) and the lateral projections of normal adults, measured on films of the joint.

Material and Methods

The talocrural joint was studied in 160 adult patients, 80 men (age 52 ± 23) and 80 women (age 53 ± 22). There were 10 patients in each decade. In the first decade the patients were 16–19 years old with closed epiphysis. The measurements were made on ankle films from patients with a history of ankle distortion but without fracture or dislocation. None of these patients had arthritis. The central beam was focused on the talocrural joint. These examinations were made with the patients in the supine position and with a film-focus distance of 120 cm. The film cassettes were placed directly under

the dorsal and lateral aspect of the ankle joint, respectively. Thus, no films were obtained in a potter-grid.

For comparison, the joint space of the talocrural joint was measured on films from phlebographies of the lower extremity in 198 patients, 99 men aged 53 ± 17 years and 99 women aged 50 ± 19 years. In these patients there was no history of trauma or disease of the ankle. The films were obtained with the patients in a sitting position and with the central beam focused on the mid-portion of the tibia, with a film-focus distance of 120 cm.

The joint space was measured on three locations in each of the a.p. and the lateral projections (Fig. 1). Points 2 and 5 were localized half-way between Nos 1 and 3, and 4 and 6, respectively. The measurements were made by using a regular millimetre-marked ruler, at an accuracy of 0.5 mm. The joint space was defined as the distance between the cortices of tibia and talus, perpendicular to the joint surfaces. Analysis of variance was used to evaluate the significance of differences between measuring points and between the sexes.

Results

There was no systematic difference between the right and the left ankle in either sex. Consequently, the two sides were pooled in the statistical analysis.

The joint space in men had an average width of 3.4 ± 0.4 mm and in women 2.9 ± 0.4 mm. The differ-

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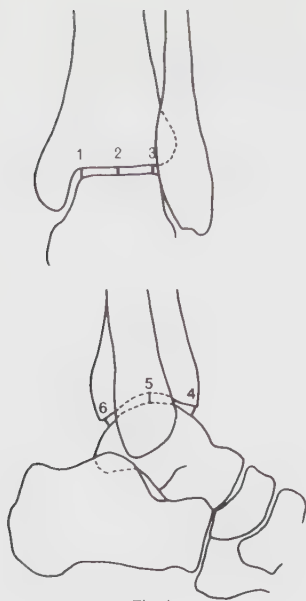


Fig. 1

Fig. 1. Measuring points of the ankle.

Fig. 2. Average joint space in each measuring point. Men (●). Women (○).

Fig. 3. Average joint space related to age. Men (●). Women (○).

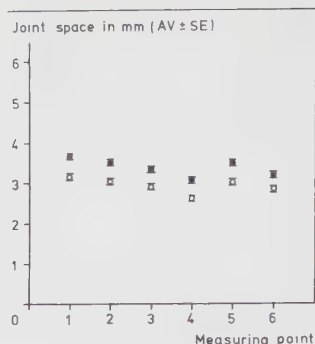


Fig. 2

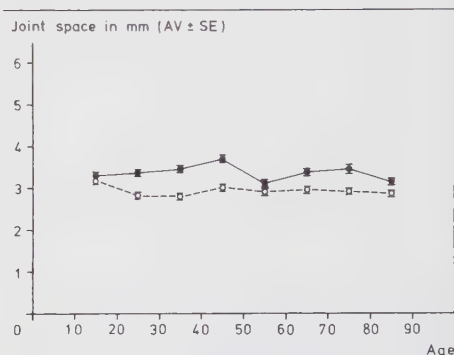


Fig. 3

ence is significant ($p < 0.001$). The joint space in each measuring point is presented in Fig. 2 and the average joint space for each decade in Fig. 3. The lowest joint width registered was 2.0 mm in women and 2.5 mm in men. In the control group the joint space had an average width of 3.4 ± 0.6 mm in men and 2.9 ± 0.6 mm in women. The average joint width was approximately 15% lower in women than in men. This difference appeared at each point of measurement (Fig. 2). The sex difference was the same when comparing the average joint width measured on phlebography films.

In the a.p. view, the joint space was widest in the medial part, decreasing in the middle and laterally. In the lateral view, the middle measurement (No. 5) had the highest score. There was no significant difference between the measuring points of the same view.

Discussion

In patients with symptoms from the ankle, i.e. after trauma or arthritis, the joint space may be affected. All the present patients had a history of trauma but comparison was made with patients without symptoms from the ankle.

In the phlebography films the central beam was focused approximately 20 cm above the talocrural joint, as compared with the regular supine examination of the ankle, where the talocrural joint is focused. This affects the points of measurements regarding the tangential view of the joint space, which is moved only a few degrees dorsally (tangents 1/6) and laterally when measured on phlebography films. The difference is negligible and for practical purposes does not affect the measurements. Comparison with examinations of the ankle with the patient supine supported this fact. With the

patient in a sitting position there is some pressure on the joint from the weight of the leg, but weight-bearing has not been reported to affect the joint space (BAUER et coll. 1978). The results in our two groups are almost identical. This indicates that the normal selection of ankle examinations is valid and the trauma in these patients per se did not affect the joint space.

There is a variation in the joint width between the different measuring points (Fig. 2). This variation may be physiologic and due to the weight-bearing function of the joint. A difference between a.p. and lateral views may be explained by different magnification on the film in the two projections.

It has not been possible to make an individual investigation of these patients regarding the annual loss of joint space. However, there is no indication of age-related loss of joint space in either sex when comparing patients in different decades of age (Fig. 3). This finding is similar to what was found in the hip (FREDENSBORG & NILSSON).

The classification of osteoarthritis in the ankle (MAGNUSSON 1944) is very approximate in describing the narrowing of the joint. The present attempt to define the normal joint space may be valuable in allowing the definition of a local arthrosis in quantitative terms as well as a more precise way of documenting a developing arthrosis over a time period.

The joint space measurements in six locations seem to cover the possible local variations of the joint space and can therefore be considered useful in population studies. The simple ruler measurement has an acceptable accuracy from routine description of the ankle joint.

SUMMARY

An investigation of the talocrural joint was performed in 160 normal adults, 80 males and 80 females. The joint space was measured on films at six locations, three in the antero-posterior and three in the lateral view of the ankle. The average joint space in men was 3.4 mm and in women 2.9 mm, which is a significant difference ($p < 0.001$). The joint space was wider in the medial part when evaluating the antero-posterior view, but did not change with age.

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III

MALLEOLAR FRACTURES. NONOPERATIVE VERSUS OPERATIVE TREATMENT

A controlled study

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ABSTRACT

Ninety-two type B ankle fractures were randomly selected for either open reduction and internal fixation or closed reduction and plaster cast. The patients were followed for an average of seven years. The initial course was more favorable in surgically reduced fractures. However, follow-up examinations showed little difference in results between the two forms of treatment.

INTRODUCTION

There are few problems in traumatology which have been discussed so thoroughly as the treatment of malleolar fractures.^{1,5,6,8,9,10,11,18,19,20,23,24,26,28,36,37,41} In spite of the intensive discussion opinions still diverge widely. Comparisons of the results of treatment have been well-nigh impossible due to differences in the classification of fractures, reduction techniques, secondary osteoarthritis, and subjective symptoms at follow-up observation.^{7,17,21,28,35,37} Therefore, operative and nonoperative treatment under the conditions of a controlled trial were compared.

MATERIALS AND METHODS

All patients with malleolar fractures admitted to the authors' institution between Feb 1, 1968 and June 21, 1970, had a standard diagnosis established by roentgen examination in three standard projections.⁵

1. A.P. view (lateral margin of the foot at a 90° angle to the horizontal plane).
2. A.P. view with the limb internally rotated 20° .
3. Lateral view of the talo-crural joint with leg and foot externally rotated 85° .

The fractures were classified using Webers criteria³⁷ (Figure 1).

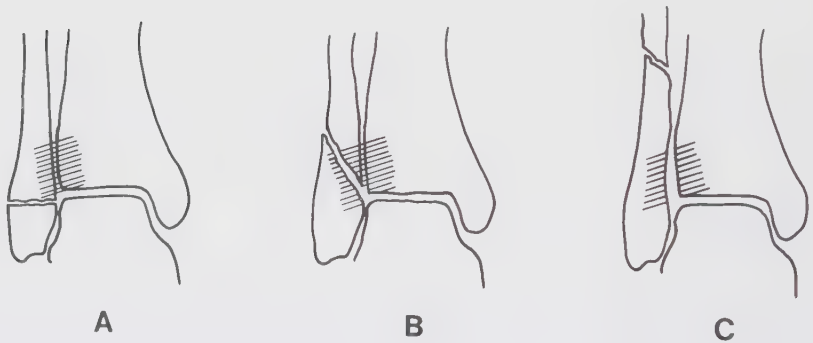


Figure 1. Classification of luxation fractures of the ankle according to Weber.

High fibular fractures with complete rupture of the tibio-fibular syndesmosis (Type C)^{7,27,29,37,38} were excluded. So were patients with open fractures and other concomitant injuries to the lower limbs. Also, patients with non-displaced fractures, patients with open growth zones and those with complicating disease which entailed increased risk, were excluded. All the others were randomly allocated to either an operation utilizing AO technique or to closed reduction and plaster cast. Random allocation was performed with the aid of a list of random numbers. Significance was tested with non-parametric tests as described by Siegel³¹ or with Student's t-test when appropriate.*

Operative treatment was performed according to the AO principles with the aim of achieving stable fixation and anatomical reduction. Ten surgeons with at least one year of experience in fracture treatment participated in the study. If possible, the patients were operated on admission or, alternatively, the operation was postponed until swelling had disappeared. General anaesthesia or peripheral nerve blocks and a tourniquet was used. Prophylactic antibiotics were not given. Ligamentous injuries were sutured. Suction drainage was applied for 24 hours. Active movements started on the first postoperative day. The patients were kept in bed with the operated leg elevated in a splint until the fifth postoperative day. In seven patients with extensive ligamentous injuries, plaster casts were used. Ambulatory postoperative treatment is summarized in Table 1.

Non-operative treatment was in all instances performed by the same group of surgeons. The stability of the syndesmosis was tested under anaesthesia in these patients: A single pointed hook was percutaneously inserted in the fibula proximal to the fracture - under fluoroscopy an attempt was made to pull the fibula in a lateral direction. This type of instability was not encountered. Closed reduction was performed and a plaster cast applied.

Postoperative radiograms were obtained immediately after closed or open treatment.

* Statistical adviser: P.O. Strangert, B.A.

Table 1. Treatment after discharge.

Control visit at	Operative treatment	Non-operative treatment
3 weeks	Wound care Roentgen	Change of plaster cast Roentgen
6 weeks	20% weight-bearing allowed	Cast removed 20% weight-bearing allowed
9 and 12 weeks	Full weight-bearing allowed Back to work?	

The patients were discharged as soon as they were able to walk on crutches. Further treatment followed the scheme in Table 1. Weight-bearing was not allowed during the first six weeks in either group to prevent load-induced displacement.^{27,38}

In those patients who were followed-up in the authors' out-patient clinic, signs of swelling,³⁰ muscular atrophy, and the time for return to work were recorded. The range of motion was measured with a goniometer taking the average of three measurements of each ankle. For the evaluation of possible residual displacement the criteria of Cedell⁷ was applied (Table 2). All films were evaluated by the same radiologist (BB).

Initially, 111 patients were included in the study. One patient died from a massive coronary shortly after the initial reduction and plaster fixation. Two nonresidents with trimalleolar fractures initially treated closed, were later operated on in other hospitals by surgeons not using the AO-technique. These three cases were considered as lost.

Protocol deviants

In eight patients, who had been randomized to the nonoperative group, acceptable reduction, i.e., lateral malleolus displacement

Table 2. Classification of roentgenologic results of reduction according to Cedell⁷

Component of injury	Anatomical	Good	Poor
Distal fibular fragment	No displacement	Slight rotation	Lateral and/or dorsoproximal displacement Marked rotation Valgus position
Medial malleolar fragment	No displacement	Slight rotation Dorsal or ventral displacement ≤ 1 mm	Dorsal or ventral displacement ≥ 1 mm. Lateral or medial displacement Marked rotation Valgus position
Deltoid ligament rupture	No displacement of the talus	No displacement of the talus	Lateral displacement or valgus position of the talus
Posterior tibial fragment	No displacement	Fragment $\leq 1/4$ of the articular surface with proximal and/or dorsal displacement ≤ 2 mm	Fragment $\leq 1/4$ of the articular surface with proximal and/or dorsal displacement > 2 mm Fragment $> 1/4$ of the articular surface with proximal and/or dorsal displacement

of less than 2 mm, was not achieved with closed reduction. Non-operative treatment was considered a failure, and operative treatment was used. Two patients, randomized to the operative group, could not be operated on because of skin damage. They were treated nonoperatively. In the analysis the ten protocol deviants were all kept in the groups to which they had been randomized.

The causes of injury and the time from accident to treatment are presented in Tables 3 and 4.

Table 3. Causes of injury.

	Op	Non-op
Slipping or stumbling	34	27
Skiing	10	17
Falling	4	9
Traffic accident	2	2
Miscellaneous	1	2

Table 4. Time from accident to treatment.

Hours	Op	Non-op
< 24	39	42
24 - 72	6	12
> 72	6	3

Table 5 shows the occurrence of Type A and B fractures in the two groups.

In retrospect, the fractures were also classified according to "malleolarity" (Table 6). This classification showed a nonsignificant tendency of extensive fractures to be more frequent in the operative group, but the difference between the groups did not reach the five per cent limit of significance. The sex and age distribution is presented in Table 7 and Figure 2.

Table 5. Fracture types in two groups.

	Weber-type		
	A	B	N
Operative group	4	47	51
(Prot.dev.*		2	2)
Nonoperative group	4	53	57
(Prot.dev.**	1	7	8)

* Prot.dev. = Protocol deviants, treated by closed reduction.

** Prot.dev.= Protocol deviants, operatively treated after closed reduction had failed.

Table 6. Number of skeletal components involved in relation to treatment.

Initially included (N = 111)

(Type A and B fractures)

	Uni	Bi	Tri
Operative group	24	8	19
Nonoperative group	38	8	14

Treated (N = 108)

(Type A and B fractures)

Operative group	24 (1)*	8	19 (1)*
Nonoperative group	38 (3)**	8 (1)**	11 (4)**

Followed (N = 92)

(Type B fractures only)

Operative group	20 (1)*	7	16
Nonoperative group	31 (2)**	7 (1)**	11 (4)**

* Parentheses contain protocol deviants treated by closed reduction.
 ** Parentheses contain protocol deviants operatively treated after closed reduction had failed.

Table 7. Sex and age distribution.

	N	M/F	Range	Mean age
Operative	51	24/27	17-76	42
Nonoperative	57	20/37	16-77	45
Total	108	44/64	16-77	44

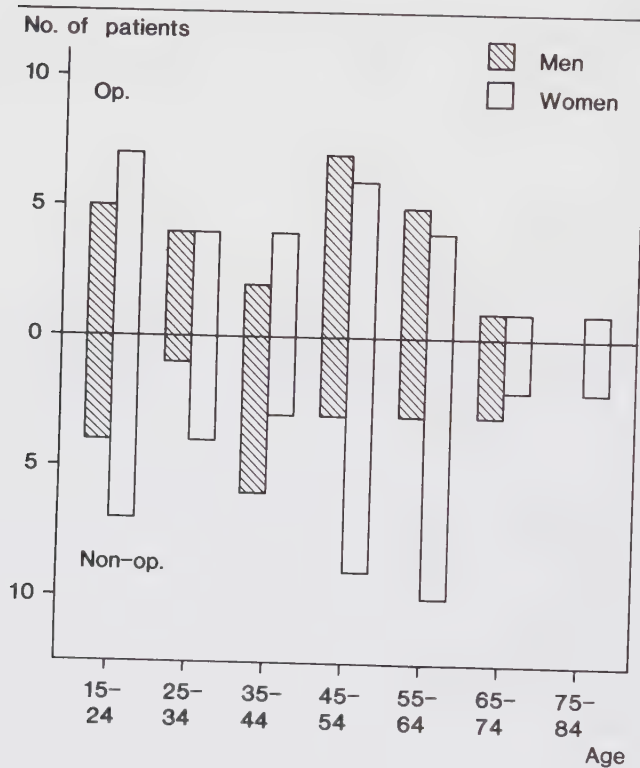


Figure 2. Sex and age distribution.

EARLY RESULTS

All fractures consolidated properly. The fractures randomized to operative treatment healed in a better position than those randomized to closed reduction ($p < 0.001$) (Table 8). The results of surgery tended to be poorer in patients who, although randomized to closed reduction, were operated on after that treatment had failed. In none of the seven such patients with Type B fractures was reduction considered anatomical. But, even when the results obtained with the two methods were compared irrespective of the patients' group-belonging, there was a significant difference in favor of operative treatment ($p < 0.001$).

Table 8. Degree of reduction.

	Anatomical	Good	Poor	N
<u>Type A fractures</u>				
Operative group	4	0	0	4
Nonoperative group	2	1	1	4
(Prot.dev. *)	1	0	0	1)
<u>Type B fractures</u>				
Operative group	23	13	11	47
(Prot.dev. **)	0	0	2	2)
Nonoperative group	4	16	33	53
(Prot.dev. *)	0	3	4	7)

* Prot.dev. = Protocol deviants, treated operatively after closed reduction had failed.

** Prot.dev. = Protocol deviants, treated by closed reduction.

The patients randomized to closed methods left the hospital significantly ($p < 0.05$) earlier than those allotted to the operative group - mean 5.0 days (0-19) as compared with 9.5 (2-33). Seventeen nonoperatively treated cases could be handled as outpatients. The mean time for treatment in cast was 6.2 weeks (4 -

16) for the nonoperative group and 6.6 (2.5 - 10) for those 7 of the 51 operatively treated patients who had postoperative plaster cast. The median time of fixation was 6 weeks in both groups.

Complications

Four infections occurred, all four in patients of the non-operative group who were operatively treated after closed reduction had failed. Two of these patients had a slight wound rash and two patients had suppuration with positive cultures. Two patients had necrosis of the skin covering the osteosynthesis devices in the medial malleolus. All patients healed without further operation. Three patients treated by closed methods had clinical signs of deep vein thrombosis, one with nonfatal pulmonary embolism; also one operated patient with and one without postoperative plaster had signs of venous thrombosis.

The median time of sick leave reported was 14 weeks in both groups, the range was four to 49 weeks for the operative group and three to 63 weeks for the nonoperative group and 23 weeks for the protocol deviants. This estimate applies only to fully employed patients and includes the sick-leave required for removal of implanted material.

Range of motion

Final range of motion of the fractured ankle was attained after an average of nine weeks (range six to 12) in the group allotted to operation as compared with 12 weeks (range nine to 15) in that allotted to closed methods ($p < 0.01$).

Swelling

In both groups swelling decreased from three weeks until six weeks after the injury (Figure 3) and continued to decrease in the operatively treated group. However, the swelling increased significantly ($p < 0.01$) in the nonoperative group after removal of the plaster.

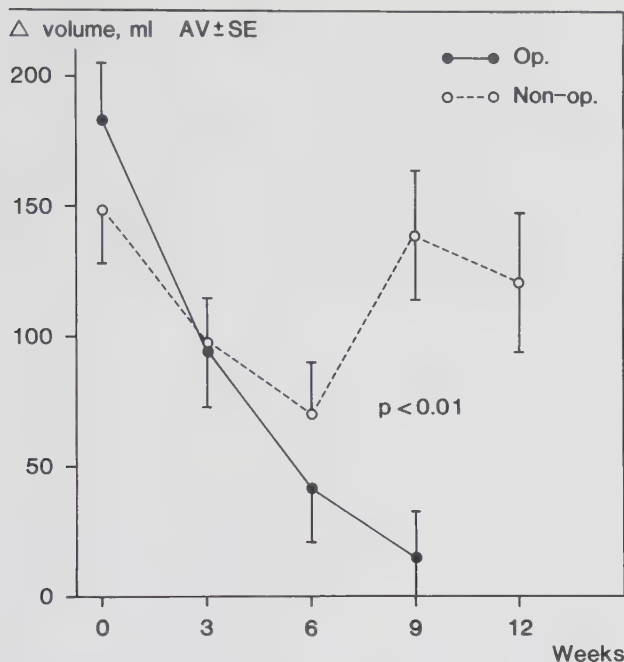


Figure 3. Swelling of fractured ankle as a function of time (injured minus controls).

FOLLOW-UP EXAMINATION

The follow-up examination was in all cases performed by two of the authors. Of the 108 patients, initially included in the study, six had died and two were lost for follow-up examination, leaving a total of 100 patients. The mean follow-up time was 7 years (range six to 8).

Ninety-two patients with Type B fractures and eight with Type A fractures were re-examined. This presentation will deal only with Type B-fractures. The sex and age distribution at follow-up observation is shown in Table 9. One of the ten patients in whom treatment had deviated from protocol was dead and one had a Type A fracture. Thus, there were seven patients who had been treated operatively after closed reduction had failed and one patient who had not been treated operatively in spite of his being allotted to operation.

Table 9. Sex and age distribution at follow-up examination.

	N	M/F	Range	Mean age
Operative	43	18/25	24-82	48
Nonoperative	49	16/33	24-85	51
Total	92	34/58	24-85	50

To estimate their subjective discomfort and their ability to work and participate in sports, the patients answered a questionnaire (Table 10).

The clinical examination included ranges of motion, dorsiflexion in weight bearing, swelling,³⁰ atrophy, tenderness, foot deformity and walking.

Roentgenographic examination included examination of both ankles in all patients by the same standard technique used for the original fracture. All exposure angles were secured using the device described by Bohlin.³ An additional view of the ankle was obtained in weight bearing with a horizontally directed beam.² All radiograms were analyzed by an experienced radiologist. Arthrosis was classified by means of follow-up radiograms using the classification of Cedell⁷ and Magnusson²² (Table 11).

Table 11. Classification of arthrosis deformans according to Cedell⁷ and Magnusson.²²

Degree	Roentgenological changes in the joint
1	Slight reduction of the joint space and slight formation of deposits on the joint margins.
2	More pronounced changes than mentioned above, possibly with the addition of a sclerotic configuration within the subchondral osseous tissue of the tibia.
3	The joint space only about half as high as that of the uninjured side and rather pronounced formation of deposits.
4	The joint space has quite or almost disappeared.

Question	Answers		Significance
	Op (N = 43)	Nonop (N = 49)	
1. Could you describe your troubles from the ankle as: None or negligible?	32 (1)	35 (3)	
2. Which are your problems?			
Swelling	15 (0)	8 (3)	p < 0.05
Pain	13 (0)	14 (4)	
Unsteadiness	4 (0)	12 (2)	
Restricted range of motion	9 (0)	6 (2)	
Passing stiffness	5 (0)	7 (3)	
3. Do you have walking difficulties			
On rough ground?	11 (0)	11 (1)	
On even ground?	4 (0)	7 (1)	
4. Can you run			
Even for long distances?	29 (1)	26 (2)	
For a short distance?	12 (0)	14 (2)	
Not at all?	3 (0)	2 (1)	
5. Do you need an elastic bandage?	1 (0)	2 (1)	
Do you need a walking stick?	0 (0)	2 (1)	
Do you take analgesics?	2 (0)	5 (1)	
6. What are your sports activities?			
Regular sports activity without problem	19 (0)	26 (3)	
(what sports)	0 (0)	3 (0)	
Reduced sports activity after the fracture	12 (0)	12 (2)	
Increased discomfort after physical efforts	0 (0)	6 (1)	p < 0.05
Have you had to stop all sports activities due to your ankle?	0 (0)	6 (1)	
7. Do you have symptoms at work?			
No symptoms	33 (1)	38 (5)	
Symptoms at the end of the day after work	2 (0)	5 (1)	
Symptoms during work	7 (0)	7 (2)	

The first figure gives the number in the group randomized to operation, the second that in the group randomized to nonoperative treatment. Numbers in brackets designate patients not treated according to the method to which they were randomized (protocol deviants).

LATE RESULTS

Symptoms

The patients' complaints are presented in Table 10. Sixty-seven patients had no or negligible symptoms. Fourteen patients in the nonoperative and 11 in the operative group complained of significant symptoms. The most common symptoms were pain and swelling. Women had symptoms twice as often as men, 19/58, as compared with 6/34, but the difference was not statistically significant.

Four patients, two in each group, had changed occupation or quit working because of ankle symptoms. All four had been employed in heavy manual labor before the injury.

There were no consistent differences between the operatively and nonoperatively treated patients with regard to subjective symptoms. Among those 20 patients who had had their fractures treated with an anatomical reduction, 14 were free of symptoms.

Clinical findings

Clinical findings are presented in Tables 12 and 13. No significant differences between the two treatment attitudes could be demonstrated except for malleolar circumference which was greater in the operated ankles ($p < 0.05$). (Mann Whitney U-test).

Table 12. Clinical findings I. Differences in malleolar circumference, volume and calf circumference in relation to treatment.*

	Δ mall.circumf.(cm)	Δ volume (ml)	Δ calf circumf.(cm)
	Av $\pm$ SD	Av $\pm$ SD	Av $\pm$ SD
Operative	0.4 $\pm$ 0.6	19.0 $\pm$ 55.7	0 $\pm$ 0.6
Nonoperative	0.3 $\pm$ 0.8	12.7 $\pm$ 51.6	0.2 $\pm$ 0.6

* Injured minus controls.

Table 13. Clinical findings II. Differences in dorso-plantar flexion, dorsiflexion in weight-bearing and pro-supination in relation to treatment.*

	Δ dorso-plantar Av $\pm$ SD ($^{\circ}$)	Δ dorsiflexion (WB)** Av $\pm$ SD ($^{\circ}$)	Δ pro-supination Av $\pm$ SD ($^{\circ}$)
Operative	-4.3 ± 7.2	-4.0 ± 4.9	-1.4 ± 3.5
Non-operative	-3.4 ± 9.3	-3.3 ± 8.5	-1.8 ± 4.4

* Injured minus controls.

** WB = weight-bearing.

Eight patients in the nonoperative and six in the operative group had pain on medial or lateral palpation. Two of the patients in the nonoperative group were protocol deviants.

Five operatively treated and three nonoperatively treated patients, had slight uni-lateral pes planovalgus deformity - only two of these ankles had been reduced to an anatomical position. Twelve operatively treated patients had minor sensory disturbances in relation to the scar.

Two operatively treated and one nonoperatively treated patient walked with a limp, two had severe arthrosis, whereas the third, an operatively treated patient, had no arthrosis. All were middle-aged women.

Because of the difference - although nonsignificant - between the two treatment groups in their number of malleolar components a post randomization stratification of the data was undertaken and the results compared within each group of skeletal involvement. In subjective symptoms there was no significant difference in the outcome. For unimalleolar fractures it could be demonstrated that the operatively treated cases had a greater malleolar circumference ($p < 0.05$) whereas for the other clinical variables and

for bi- and trimalleolar fractures, no significant differences could be demonstrated between the two treatments.

Also, ankles reduced to an anatomical position did not differ significantly from those operated on with less success.

Excluding protocol deviants from the analysis did not affect the outcome, except that the difference in malleolar circumference became more marked ($p < 0.01$).

Including the protocol deviants in the groups to which they were transferred changed the outcome in one respect only. Severe arthrosis (degree 2-4) became significantly ($p < 0.05$) more common in the operated group.

Roentgenological findings

The degree of arthrosis in relation to treatment and results of reduction is shown in Table 14. There was a nonsignificant tendency to less arthrosis among those patients who were reduced to an anatomical position.

Table 14. Arthrosis in relation to reduction and type of treatment

Reduction		Degree of arthrosis				
		0	1	2	3	4
Operative group	Anatomical	8	8	3	1	
	Good	3	6	4		
	Poor	1	4(1)	1	2	2
Nonoperative group	Anatomical	2				
	Good	6	8(2)	1(1)		
	Poor	9	13	3(1)	6(2)	1(1)

Figures in parentheses = protocol deviants.

Roentgenological findings of arthrosis (degrees 1 - 4) were noted in 72 per cent of the operative and in 65 per cent of the non-operative group (n.s.). All eight protocol deviants developed arthrosis.

Trimalleolar fractures developed arthrosis significantly more often than unimalleolar fractures ($p < 0.001$) (Table 15). If the outcome was compared within each group of skeletal involvement, there were no significant differences between the two methods of treatment. The skeletal involvement at injury thus appears to be of greater importance for the outcome than the choice of treatment.

Further, there was a positive correlation between age and arthrosis ($p < 0.001$).

Finally, examination of films exposed under weight-bearing did not change the outcome of the analysis.

Table 15. Degree of arthrosis in relation to skeletal involvement and treatment.

		Unimalleolar		Bimalleolar		Trimalleolar	
		Op	Non-op	Op	Non-op	Op	Non-op
Arthrosis	0	9	16	2	1	1	
	1	8(1)	12(1)	4	3	6	6(1)
	2	3	3(1)	1	1(1)	4	
	3				2	3	4(2)
	4					2	1(1)

Figures in parentheses = protocol deviants.

DISCUSSION

The present study was performed according to the rules for controlled clinical trials,¹⁴ i.e., the patients were randomly allocated to either closed or open treatment and the results were assessed in an unbiased manner.

The crucial question is whether or not the two groups are comparable. As seen in Table 2, there was no significant difference between the two groups as to the type of injury. Neither were there significant differences as to fracture type (Table 5), sex and age (Figure 2) and time between accident and treatment (Table 4). However, as seen in Table 6, there were more trimalleolar fractures in the operated group. Although this difference was not significant, it implies a disadvantage for the operated group, and this should be kept in mind when the results are evaluated.

The next question is whether the comparison reflects the difference between the two methods? For various reasons, eight patients randomized to nonoperative treatment had to be treated operatively, whereas two patients were treated nonoperatively, although they had been randomized to operation. In other words, the problem of protocol deviants, a common occurrence in surgical trials was encountered.⁴ In order not to impair comparability, the deviants were kept in their original groups. Under such conditions, however, the comparison no longer differentiates between the two methods per se. Instead, it reflects the difference between two therapeutic attitudes, one primarily operative and one primarily non-operative. This does not detract from the value of the comparison. On the contrary, it has even been claimed that such a comparison more closely reflects the conditions of clinical practice.³³

Is there a risk that differences are being concealed? Obviously small differences will remain undetected since the short series and the poor precision in many of the methods involved will imply a risk for a type II error.

Finally, it is necessary to consider to what extent the results of the present study can be generalized to other surgeons. In the present study, 10 surgeons who had highly varying levels of training participated. No effort was made to restrict their number for the sake of uniformity. The absence of such restrictions probably increased variance, but it also tended to increase the possibility of inference.³⁴ This means that the results would be more likely to be valid for surgeons in general, an intentional objective of this study.

Although the operative group was at a disadvantage, in so far that it contained more trimalleolar fractures (Table 6), the results of reduction were superior to those in the nonoperative group. Moreover, closed treatment failed in no less than eight of 57 cases. For obvious reasons, the results of subsequent operations were poorer in these eight cases. Not only were the results of reduction superior in the operative group, but patients in that group also tended to regain their final range of motion sooner than those in the nonoperative group. The initial sick leave was also slightly briefer in the operative group. This advantage was, however, offset by the time of incapacity following extraction of the osteosynthetic devices. As a result, the total length of sick leave was about the same in both groups. The price which has to be paid for the superior early results of operative treatment is a longer duration of hospitalization.

However, these superior early results in the operative group were not reflected by a similar difference in the late results.

With as many as 100 of the 102 survivors reexamined, there is no need to worry about the effect of selection. A follow-up examination after on average seven years should also be adequate. Several studies have shown that no significant change in post-traumatic arthrosis rate occurs after the first years.^{7,16,17,21,25,38}

Presented here, separately, are the data reflecting subjective discomfort, the clinical and roentgenographic findings, and com-

parison of the two policies of treatment for the individual variables. Some authors^{13,15} have used a combination of roentgenographic findings and clinical and subjective variables in which poor results may be based on roentgenographic criteria alone, in spite of excellent clinical results. As pointed out by Phillips and Spiegel²⁸ such a rating system tends to downgrade closed reduction radiographically and upgrade open reduction.

As expected, operative treatment resulted in a better reduction than nonoperative treatment. However, an anatomical reduction was not always achieved at operation. This may have been due to the loss of bony substance, to technical difficulties, or to the varying degrees of training of participating surgeons.

The seven Type B fracture patients who, although randomized to closed reduction, had to be treated operatively, possibly had more severe fractures since they could not be reduced to an acceptable position even by open reduction (Table 8). All four infections occurred in these patients.

In this investigation, it was possible to compare the results of two different attitudes to treatment of ankle fractures. However, comparison with other series is not possible due to differences in classification of fractures and degree of reduction.^{7,15,16,17,22,32,35,37,39} For the radiologic classification of reduction, the criteria of Cedell⁷ were selected. He obtained better results with operative reduction than in the present study: his fracture classification is, however, different. Lindsjö²¹ and Weber,³⁷ who accept only minimal displacements, also present better results of reduction. More liberal limits for acceptable reduction have been suggested by Vasli.³⁵ As an example, 2-5 mm:s displacement of the fibula is defined as "medium" positional reduction, whereas according to Cedell⁷ this position would be "poor".

In this series almost 30 per cent (25/92) of the patients have residual subjective discomfort more than five years after the injury. This is in accordance with the findings of other authors.

For closed reduction Magnusson²² reported 33 per cent and Klossner¹⁶ 27 per cent with late subjective discomfort. For operatively treated patients, Cedell⁷ reported 27 per cent in his total series and Klossner¹⁶ had 28 per cent residual complaints. Wilson and Skilbred⁴⁰ found that 65 per cent of the patients in their mixed series had complaints. As subjective discomfort is only one part of the total score of the AO-classification, it is difficult to make a direct comparison with Forudastan,¹³ whose operatively treated patients had 77 per cent excellent results, or with Hughes et al.,¹⁵ who found 17 to 24 per cent poor results with operative treatment of Type B fractures; 57 to 65 per cent poor results was noted in the nonoperative group.

The present study failed to demonstrate any difference between the two groups of treatment in subjective symptoms; some small differences - swelling, sports activities - may be due to spurious significance.

Although comparisons are difficult, the incidence of arthrosis was high in the present series, especially in the operatively treated group. A possible reason is the fact that reduction in the present series was less satisfactory than in some of the previous studies.^{7,21, 37} However, fractures reduced to an exact position (20 in the operative, two in the nonoperative group) still had a remarkably high rate of arthrosis (60 per cent of the operated) (Table 14). This suggests that factors other than the mere restoration of the congruency of the joint surfaces may play a role. It should, however, be kept in mind that the slightest degree of arthrosis - degree 1 in the present study - was the most common and is the most difficult to define.

Wilson and Skilbred⁴⁰ found that operative exact reduction more often caused arthrosis than nonoperative exact reduction. They state: "Whether the higher incidence in patients undergoing open reduction is coincidental or reflects added trauma is unknown." Since their series was retrospective and not randomized, the more severe fractures were perhaps more likely to have been subjected to operation and this would have biased their comparison. This

type of bias, can be excluded in the present series, but the results still suggest that the operation may add to the trauma. Other factors predisposing to late discomfort and arthrosis, may be primary injury to cartilage and/or soft tissue, as suggested by Felsenreich.¹² The extent of skeletal involvement is probably a more reliable indicator of the severity of the trauma than the classification into A, B and C fractures which does not reflect this quality.

For summary of the present clinical trial, the initial results indicated a more favorable early course in the patients randomized to surgery. At follow-up examination, however, patients randomized to closed reduction had long-term results comparable to those randomized to operation.

A policy of operative treatment of ankle fractures resulted in a better reduction, a more rapid decrease of swelling, and a more rapid regaining of motion than a policy of closed reduction followed by treatment with a plaster cast. In some instances the results of the closed reduction were considered to be inadequate and the patients were treated operatively.

After an average of seven years, subjective symptoms were comparatively frequent and present in about 1/3 of the patients in both groups.

In spite of their much better postreduction position, operated fractures had a tendency to develop arthrosis and, in this respect, did not differ much from the nonoperative group.

Arthrosis could develop also after operative reduction to an exact position: in contrast, joints healed in a poor position could be free from arthrosis.

There was a comparatively poor relation between the initial results of reduction and the development of arthrosis later on, suggesting that factors other than the treatment may play a role for the outcome. This is supported by the finding that the degree

of skeletal involvement, presumably a measure of the severity of the causative trauma, is of great importance for the production of arthrosis.

Because the classification in A, B and C fractures is relatively insensitive to the degree of skeletal involvement, comparisons in and between series classified with that method should be performed only when hidden stratifications can be ruled out.

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IV

Thirty-year follow-up of ankle fractures

The natural course of ankle fractures was studied in 143 patients treated by closed methods. The average time elapsing from fracture to follow-up was 29 years. Eighty-two per cent had no radiographic signs of arthrosis; 83 per cent were free of symptoms. The most common fracture, supination eversion Stage II (49 cases), gave rise to minimal signs of arthrosis in only one patient, who had moderate symptoms.

The suggestion that all ankle fractures must be perfectly reduced is not supported by the findings of the present study.

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It is unfortunate that the natural course of ankle fractures is not known: neither the occurrence of disability nor the significance of radiographic changes. We have examined a series of ankle fractures, on average almost 30 years after treatment by closed methods.

Patients and methods

Patients

The fractures had occurred in Malmö in the early 1950's in subjects who were still residents of the city, were under the age of 85 years and were available for follow-up – the cases were, otherwise, consecutive. Seventy-six patients declined to participate but no significant deviation with regard to fracture type, age or sex in relation to the examined patients was found in this group. The original sample thus collected consisted of 170 patients. Seven patients were excluded because of additional fractures in the same or the opposite side. Ten patients later had another ankle fracture and were excluded as well. Ten patients had originally been operated on and were also excluded, leaving 143 patients for examination: 81 men and 62 women, aged at the time of fracture 37 ± 9 and 40 ± 9 years, respectively. The time lapse between fracture and follow-up was 29 (25–34) years. The age at the time of follow-up was 67 ± 9 years.

Fifty-seven per cent of the fractures had been caused by a mild or moderate trauma such as tripping, stumbling, or falling at ground level. In 19 per cent there was a more severe trauma. Twenty-one per cent had occurred in a traffic accident, often involving bicycles, where the severity of the trauma was difficult to establish. Three per cent were caused by direct trauma.

Methods

Patients were interviewed in a standardized way regarding subjective symptoms, and the Cedell (1967) classification of symptoms and late objective results was used.

The clinical examination included measurements of ranges of motion compared with the contra-lateral side and of swelling (Sandegård 1974).

Radiographic examination. Three standard projections, antero-posterior, lateral and 20° inward rotation projection of the joint, were obtained of both ankles, and the following films were studied:

- (1) The *initial* films showing the fracture at the time of admission.
- (2) Films obtained *after casting* with or without reduction.
- (3) Films showing the position in which the fracture was allowed to heal – *the accepted position*.
- (4) Films taken at the *follow-up*.

The type of fracture (Table 1) was classified according to Lauge-Hansen (1942, 1954) and Weber (1972).

The degree of displacement was evaluated. The size of the posterior fragments was measured and expressed as the percentage of the joint surface carried by the fracture fragment in the lateral view. Attempts were made to quantify displacement in mm, whereas rotation malposition was estimated and classified in 4 grades from 0 (no rotation) to 3 (marked rotation).

In the radiographic examination at the follow-up, attention was paid to the presence or absence of secondary arthrosis. The *joint space* was measured at six sites of the joint (Jonsson et al. 1984). The presence or absence of juxta-articular cysts and sclerosis

Table 1. Ankle fractures. Type and degree of arthrosis at follow-up

Fracture type		Arthrosis degree ^a					Total
		0	(*)	*	**	***	
<i>Weber</i>							
A		19		1			20
B		85	6	7	3	2	103
C		13	3	1	3		20
Total		117	9	9	6	2	143
<i>Lauge-Hansen</i>							
Supination-adduction	I	10					10
	II	4		1			5
Supination-eversion	I	1					1
	II	48	1				49
	III	10		2			12
	IV	24	5	4	3	2	38
Pronation-abduction	I	4					4
	II	4	1	1	1		7
	III	3					3
Pronation-eversion	I	2					2
	II						0
	III	5		1			6
	IV	2	2		2		6
Total		117	9	9	6	2	143

^a Magnusson (1944), Cedell (1967)

was noted, as was the presence and location of osteophytes. In addition, the arthrosis classification of Magnusson (1944) and Cedell (1967) was used.

Results

Of the 143 patients only five had, over the years, sought medical advice for their ankle once the initial period of pain and discomfort was over.

At follow-up 118/143 (83 per cent) had no subjective complaints; 24 had occasional pain or aching.

There was no significant difference in volume between the injured and the uninjured lower limb. The range of motion in extension and flexion was equal in both ankles in 90/143 of the patients, and 121/143 also had equal range of motion in pro- and supination.

Tenderness on palpation was present on the medial side in four ankles and on the lateral

side in two ankles. A uni-lateral foot deformity on the fracture side was found in two patients.

Of the 143 patients, 117 were free of radiographic signs of arthrosis, and marked arthrosis was observed in only two ankles. Arthrosis was more common in the initially more severe fractures (Table 1).

In a multiple regression analysis of the 100 supination-eversion fractures of all stages, comparing the positions in which the fracture was left to heal with arthrosis and dysfunction, there were significant correlations between a poor outcome and the displacement of the medial malleolus and the size and displacement of a posterior fragment – all interacting with the severity of the injury.

Isolated lateral malleolar fractures

Arthrosis had developed in only one case of the most common type of ankle fracture, the lateral malleolus (Lauge-Hansen supination-eversion (SE Stage II)); the patient had moderate symptoms (Table 1). In most of these fractures some displacement had been accepted. Displacements of the lateral malleolus of up to 3 mm did not seem to cause arthrosis (Figure 1). Of the 49 patients only three had subjective complaints. One of these was the patient with arthrosis. They all participated in sports and the worst impaired still took daily walks of up to 3 hours. The rest were largely free of subjective symptoms, often having difficulty in telling which ankle had been fractured. Using the criteria of Cedell (1967) for late subjective and objective results, there were 47 good and 2 medium late subjective results, and 46 good, 2 medium and 1 poor objective results – the poor results consisting of a 2.5 cm increase of the malleolar circumference unassociated with any symptoms whatsoever.

Supination-eversion Stage IV injuries

There were 38 supination-eversion Stage IV injuries. Twenty-nine patients were free of symptoms. Twenty-four patients were free of radiographic signs of arthrosis (Table 1). There was no difference in age at the time of the injury, either between men and women, or between SE II and SE IV fractures.

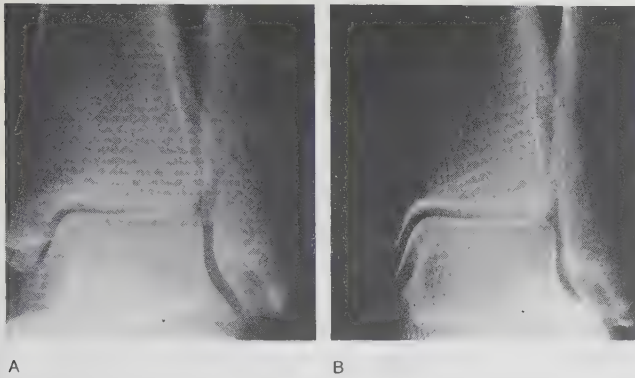


Figure 1. Woman, age 43 – skiing accident. Supination-eversion Stage II fracture left ankle. A. Three mm lateral displacement of distal fibula fragment. No reduction, cast for 3 weeks. B. Follow-up 30 years later. No subjective complaints. Malleolar circumference +0.5 cm. No arthrosis.

All SE IV injuries were categorized as Weber type B and so were all SE II injuries except one (A-fracture). Weber type B thus comprised fractures with totally different prognoses.

Discussion

The best treatment of ankle fractures is much disputed and no consensus has been reached (Phillips & Spiegel 1979). If the discussion is limited to the lateral malleolar fracture, opinions range from “no importance at all” (Cox & Laxson 1952) to “it has the key role” (Yablon et al. 1977). Böhler (1957) stressed the importance of an anatomical reduction to avoid later disability and arthrosis. The consequences for the weight-bearing function of the ankle of even minor displacements of the lateral malleolus have been pointed out by Riede et al. (1969); even minor lateral or rotational displacement reduces the talar contact area to a considerable degree. The increased load on the joint surfaces after fractures left in a displaced position was then thought over the years to lead to an incongruence arthrosis (Riede et al. 1971).

Good results after conservative treatment of isolated lateral malleolar fractures (SE II) have been reported by Kristensen (1956), Paul et al. (1968) and Muschter & Götz (1974). Solonen & Lauttamus (1965, 1968) advocated open treatment and so did Cedell (1967), who in 38 cases treated openly, found only one with a slight arthrosis. Lange et al. (1984), using the criteria of Bargon (1978), never found ad-

vanced arthrosis in SE II fractures treated openly according to the AO-principles. Lindsjö (1981) also had good clinical results with AO-operations of SE II fractures. In a comparison between open and closed treatment of SE II fractures with a minimum follow-up of 3 years, Yde & Kristensen (1980b) found no difference in the outcome. Wilson (1975) considered SE II injuries stable and requiring no reduction.

An important factor in the treatment is the correct classification of SE fractures. The presence or absence of lesions on the medial side of the joint must be noted (Phillips et al. 1969). A rupture of the deltoid ligament renders the seemingly innocent Stage II injury an unstable SE IV injury with a possibility of talar dislocation. Series of conservatively treated SE II injuries may erroneously include a few SE IV injuries, downgrading the result (Cedell 1967, Yde-Kristensen 1980a,b).

The idea that all ankle fractures must be perfectly reduced is not supported by the findings of the present study. As for those few cases which had severe arthrosis, they had all had extensive fractures, as reflected in their Lauge-Hansen stages. Our data are not suitable for a more detailed analysis of the effects of treatment.

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V

SUPINATION-EVERSION FRACTURES OF THE ANKLE JOINT - CHANGES OVER 30 YEARS

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INTRODUCTION

Over the last 30 years the age specific incidence of lateral malleolar and trimalleolar fractures in elderly women and in men in the city of Malmö increased.³

In previous studies on ankle fracture epidemiology^{3,11} incidence calculations have been based on the bone involvement, i.e. which and how many malleoli were involved. This is a reasonable approach when we want to evaluate the importance of bone fragility for the production of these fractures. For the more practical purpose of selecting treatment, however, a genetic classification such as that of Lauge-Hansen⁸ is more useful. This method of classification is advantageous not only for its original purpose - nonoperative treatment of ankle fractures - but also for selection between nonoperative and operative methods.^{1,5} Therefore, the secular trends of change with regard to genetic types of ankle fractures should be important.

MATERIAL AND METHODS

The population of the city of Malmö was 192.000 in 1950 and is presently 230.000. The proportion of elderly has increased over the years.^{3,6}

All ankle fractures in residents of the city are diagnosed in the

Department of Diagnostic Radiology, Malmö General Hospital, usually also those incurred outside the city. Registration routines have remained unchanged over the years. All films have been saved.

All films of ankle fractures from 1950-54 and 1980-84 were re-examined and classified according to Lauge-Hansen.⁸ Age- and sex-specific incidences for the main types of fracture were calculated using the population census figures of the city files.

RESULTS

Altogether 1.784 fractures were found. In the 5 year sample from the 1950's there were 324 men and 281 women and from the 1980's 550 men and 629 women. The fracture type distribution is shown in Table 1. Three types were sufficiently common to permit comparisons between the two time periods, namely supination-eversion fractures stages II and IV (SE II and SE IV) and pronation injuries - all included (P).

In the 1950's 61% of the ankle fractures in women and 57% of those in men were of the supination-eversion type (SE). In the 1980's supination-eversion contributed 68% of the ankle fractures in women and 67% in men.

The age- and sex-specific incidence for the three most frequent types of injuries is presented in Figure 1 where also the two sets of fractures - the 1950's and the 1980's - are compared.

In SE II injuries there was a significant increase ($p < 0.01$)* in middle-aged and elderly women. In men there was a significant ($p < 0.001$)* increase in the young and middle-aged.

SE IV fractures had increased ($p < 0.001$)* in elderly and in middle-aged women - there was also some increase in men.

Pronation injuries had increased slightly in men during the last
* Chi-square analysis

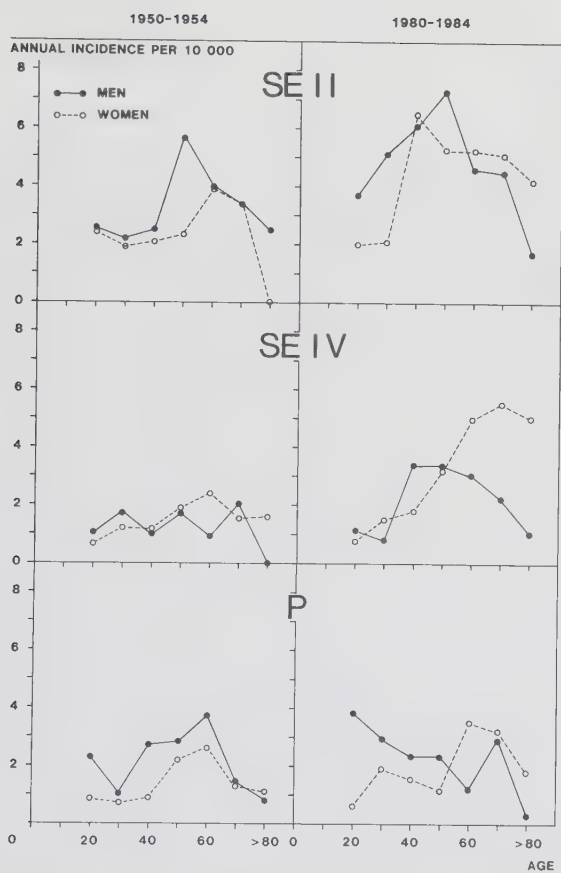


Figure 1. Annual incidence per 10.000 of supination-eversion injuries stage II (SE II) and stage IV (SE IV) and of all pronation injuries (P).

30 years.

Table 1. Distribution of fracture types according to Lauge-Hansen.⁸

Type	Stage	Men				Women			
		1950-54		1980-84		1950-54		1980-84	
		N	%	N	%	N	%	N	%
Supination-adduction	I	40	12	52	9	44	16	83	13
	II	11	3	10	2	2	1	6	1
Supination-eversion	II	118	36	231	42	100	36	226	36
	III	19	6	36	7	12	4	31	5
	IV	48	15	98	18	60	21	169	27
Pronation-abduction	I	20	6	33	6	4	1	22	3
	II	10	3	8	2	0	0	5	1
	III	21	6	16	3	17	6	28	4
Pronation-eversion	III	21	7	24	4	12	4	18	3
	IV	12	4	32	6	26	9	27	4
Unclassifiable		4	1	10	2	4	1	14	2
Total		324		550		281		629	

N.B. PA I and PE I injuries cannot be differentiated from the radiograms. All have been included in the PA I group. For a correct diagnosis of SE I and PE II injuries the anterior tibial tubercle must be well visualized. On standard films this is not the case, which explains why no such fractures were encountered here. Unclassifiable: Most of these were isolated fractures of the posterior tibia margin.

Even if - in women - both SE II and SE IV injuries have increased, the ratio has changed during the 30 years under study. Today a much larger portion is the more severe SE IV-injury (Table 2).

Table 2. Ratio between SE IV and SE II injuries in relation to sex, age and time period.

Age group	1950-54		1980-84	
	Men	Women	Men	Women
< 50	0.45	0.57	0.37	0.44
50 >	0.33	0.63	0.49	0.98

DISCUSSION

Altogether the incidence of ankle fracture in the city has almost doubled - this is due to an increase in the proportion of elderly in the population⁶ and to the change in actual risk demonstrated by Bengnér et al.³

For the most common genetic trauma - the supination-eversion - the fracture outcome has changed over the years. This has consequences for therapy. The most common - the SE II injury - has an excellent prognosis even without operation.^{1,7,13} This fracture has become more common but the increase has been moderate - in younger men it is possibly related to increased physical activity and trauma risk. It is, however, the increasing number of SE IV injuries in elderly women that constitutes a therapeutic problem. These patients may be unsuited for surgery because of their general condition of health. Also, the bone fragility of elderly women will cause difficulties in achieving stable fixation. Unfortunately, in this group the results attained appear to be the worst regardless of treatment.^{2,4,9,10,12}

The SE IV injuries have today the age- and sex-pattern of a bone fragility fracture. The trend of change may require variation in the therapeutic approach - less extensive surgical procedures and

perhaps also nonoperative treatment may be justified.

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GENERAL DISCUSSION

GENERAL DISCUSSION

Occurrence of ankle fractures

Buhr & Cooke (1959) found that ankle fractures were 11 per cent of all fractures. In the incidence study of Nilsson (1969) ankle fractures increased in peri- and post-menopausal women but became again less frequent with increasing age. However, in recent years the risk of fracture has increased for the most common type - the SE fractures (V). Furthermore the more extensive fracture - the SE IV type - has changed its age specific incidence and become a fracture of the elderly, i.e. the elderly woman. This distribution which suggests that bone fragility has become an increasingly important factor for the etiology of ankle fractures will no doubt affect also our thinking with regard to choice of treatment.

Similar shifts in fracture patterns, an increase in the elderly, have been described for the hip (Zetterberg & Andersson 1982, Wallace 1983, Zain Elabdien et al. 1984, Johnell et al. 1984, Nilsson 1984) and for the distal end of the forearm (Bengnér & Johnell (1985)).

Classification of ankle fractures

The simple anatomical subdivision into uni-, bi- and trimalleolar fractures does not take into account soft tissue injuries, not visible in the radiogram (Malka & Taillard 1969), nor does it explain the type of trauma or the sequence of injury events. When Ashurst & Bromer (1922) published their classification of ankle fractures, this was the first more generally accepted system. It is still used by some authors (Denham 1964, Brodie & Denham 1974, Purvis 1982) and in a modified form by Wilson (1975). This system has been criticized since it fails to recognize the importance of concomitant ligamentous injuries and since it assumes that a uni-directional force rather than a combination of forces is responsible. Also, there is no progression in the severity of the acting force (Wilson 1975).

Lauge-Hansen (1942) in a series of experiments on autopsy specimens developed the so-called genetic system of classification.

Lauge-Hansen in later publications (Lauge-Hansen 1948, 1950, 1952, 1954) and Baek Kristensen (1956) proposed that this approach greatly improved the results of conservative treatment, since much better reduction was obtained. A major advantage of the classification is that it recognizes the importance of ligamentous injuries (Yde 1980, Roberts 1983) and places the individual components of injury in a sequence in time so that, when the end point is represented by a fracture, the presence of intermediary ligamentous injuries may be inferred (Burwell & Charnley 1965). McDade (1975) and Hamilton (1984) considered the Lauge-Hansen system the most comprehensive and accurate scheme available today. Its ability to accurately categorize more than 95 per cent of all indirect ankle injuries is an advantage (McDade 1975, Yde 1980, Hamilton 1984). Lindsjö (1981, 1984) was critical of the method on the same grounds - a few per cent could not be classified which has been observed by several authors (Vasli 1957, Klossner 1962, Burwell & Charnley 1965, Maatz & Nonnemann 1973). Cedell (1967) also criticized the Lauge-Hansen classification for taking into account only the radiographic appearance of the fractures and without attention to the clinical examination of the ankle - major ligamentous injury might pass un-noticed in a radiogram obtained in a reduced position. Also, the system with its many sub-groups has been considered to be too complicated for daily routine use (Jergesen 1959, McDade 1975, Lindsjö 1984). Besides, there is some confusion over the terminology (McDade 1975, Sisk 1980, Purvis 1982). The term supination-eversion is a misnomer - eversion really stands for external rotation.

Pronation injuries in the Lauge-Hansen classification are perhaps not very well defined. As pointed out by Lindsjö (1984) there is no way to differentiate radiographically between a PA I and a PE I injury. Syndesmosis injuries in these groups are also debated. Yde (1980) believes that injury to the posterior syndesmosis complex precedes the fibular fracture as a stage II injury even in the PE fractures. Weber (1972) has described similar cases, whereas Lauge-Hansen defines these as stage IV injuries (Lauge-Hansen 1942). Also, Yde (1980) could not find pathognomonic lesions on the medial side since transverse and oblique fractures as well as

ligamentous tears could occur in both fracture groups.

To spread the knowledge of the Lauge-Hansen system several attempts have been made to explain and simplify it (Arimoto & Forrester 1980, De Smet et al. 1982, Weiss et al. 1983). In a plea for simplicity, Phillips et al. (1968) add the fracture producing mechanism of Lauge-Hansen to the anatomic classification in uni-, bi- and trimalleolar fractures, the result being yet another classification which does not significantly improve the situation.

The Weber system (Weber 1966) is developed from the ideas presented by Danis (1949), the primary difference being that Danis had four groups - the high fibula fractures were divided into subcapital types (Maisonneuve 1840) and fibula fractures in the lower half of the shaft but above the anterior tibio-fibular ligament, both comprising Weber's group C including all fibula fractures above the anterior tibio-fibular ligament, since they all are combined with a syndesmosis injury (Willenegger 1961, Weber 1966). The major advantage with the Weber system is its simplicity and the emphasis it places on the tibia-syndesmosis complex (Weber 1966, Olerud 1968, Forudastan 1970, Hughes et al. 1979, Lindsjö 1984). However, it does not permit categorization of the injuries according to severity (Hamilton 1984, Phillips et al. 1985). Weber states that a syndesmosis injury never occurs with the type A fractures, whereas it is found in 50 per cent in the type B fractures and is always present when there is a type C fracture. Hamilton (1984) remarks, however, that although the Weber classification provides a statistical incidence of rupture of the syndesmosis for each fracture type, this scheme does not permit one to predict the degree of syndesmosis injury in any given patient.

Partial injuries to the syndesmotic complex such as isolated injuries to the anterior tibio-fibular ligament are the first stage of the supination-eversion fracture (SE I) (Lauge-Hansen 1942, Cedell 1967). Total injuries comprise a rupture also of the interosseous membrane and the posterior tibiofibular ligament with risk for both a true interosseous diastasis (Iselin and de Vellis 1961) and a lateral ankle instability (Kleiger 1956, Leeds & Ehrlich

1984).

However, in cases with a total rupture of the lateral structures the talus will shift laterally no more than 2 mm if the deltoid ligament is intact (Close 1956, Grath 1960, Kleiger 1961, Staples 1965).

In the prospective randomized controlled series (III) a hook was inserted percutaneously and the proximal fragment pulled in order to detect interosseous membrane rupture. None of the B-injuries had such a complete rupture of the syndesmosis, whereas many had incomplete injuries that did not disqualify them from entrance.

Also, one of the results of our study (III) was that the Weber classification is insufficient for stratification of injuries in a therapeutic trial - more accurate classification is required taking into account the severity and the extent of the injury - unless, of course, several hundred cases are included.

Even if the Danis-Weber classification only comprises three main groups, it requires the same knowledge of ankle anatomy and biomechanics for an adequate diagnosis; for each of the three types of fibula fractures there is a long list of additional injuries that might be incurred in combination with that type (Weber 1972, Lindsjö 1984)

The arguments over the classification systems and their power to describe an injury and all its components, can, to some extent be a problem of semantics. It is undeniable, however, that the radiogram does not tell the whole story of an injury. A clinical examination including the presence or absence of tenderness, swelling, bruising et cetera and an estimation of the stability, is indicated in each case of a fractured ankle (Cedell 1967, Lindsjö 1984).

Heim (1983) proposed that the issue of classification was solved with the invention and the acceptance of the Weber system but in the same paper pointed out that the classification B-fracture

is not sufficient, since among these a distinction must be made between fractures with and without posterior tibia fragments for which the prognosis is different.

Vécsei et al. (1982) make the same suggestions, the simple classification into A, B and C fractures must be abolished and these fractures must be related to their concomitant injuries, whether there is a medial malleolar fracture and/or a posterior tibia fragment et cetera.

Zenker & Nerlich (1982) made the same observations. They found a good correlation between the outcome, judged on the development of arthrosis, and the number of single lesions or as reflected in the Lauge-Hansen stages, whereas the Weber classification did not have any prognostic value. Niethard & Plaue (1977) also support this opinion.

At the time when the prospective randomized controlled series (III) was initiated, it was natural to use the Weber classification in a study of AO osteosynthesis. Only in the follow-up of these patients did it become evident that this method was inadequate.

Classification of arthrosis of the ankle

Reduction of joint space is considered to be a necessary requirement for the diagnosis of arthrosis (Magnusson 1944, Cedell 1967, Matzen & Fleissner 1969, von Elmendorff et al. 1971, Bargon 1978, Lindsjö 1981). The Magnusson-Cedell classification was used in the studies (I, III, IV) since it was thought to permit analysis in great detail. There is, however, an element of subjective estimation in this classification, most obvious in the (+) degree. We have interpreted this degree (+) as any noticeable reduction - even if not measurable - of the joint space in relation to the contra-lateral ankle. The high frequency of degree (+) lesions in the prospective randomized control series (III) as compared with the 30-year follow-up (IV) may simply be due to inter-investigator error, in spite of our efforts to attain harmony among the roentgen readings. Other explanations cannot be ruled out. The

deviation was greatest in the evaluation of the borderline (+) cases but also the more advanced degrees of arthrosis were more common in the prospective study (Table 1).

Table 1. Comparison of arthrosis-rate between the prospective randomized controlled series (III) and the 30-year follow-up (IV).

	None	(+)	+ or more
III	32%	42%	26%
IV	82%	6%	12%

Also, the possibility of long-term, fracture-induced changes in not only the fractured but also the contra-lateral ankle is to some extent supported by the joint space measurements presented in the Appendix.

Evaluation of residual displacement

Various criteria have been proposed for the radiographic evaluation of the residual displacement of ankle fractures. Baek Kristensen (1949) presented a classification which has been used with minor modifications by many authors (Biström 1952, Vasli 1957, Klossner 1962). Tolerance limits for a good position of the lateral malleolus include dorsal displacement of up to 2 mm but no lateral displacement and for the medial malleolus of up to 2 mm dorsal but no medial displacement and, finally, for the posterior tibia fragment of up to 2 mm displacement. Cedell (1967) used stricter criteria and in his "anatomical" group no displacements were tolerated, not even for small posterior tibia fragments. Yde & Kristensen (1980b) in a series of supination-eversion stage IV fractures, clearly demonstrated the differences in outcome with both classifications - the results were inferior, especially in the conservatively treated patients, when the Cedell criteria were used.

Solonen & Lauttamus (1968) also required strict anatomical

reduction of the medial and lateral malleoli, but in the "good" group still accepted small ($< 1/4$ of the surface) displaced posterior tibia fragments.

Another method of estimating residual displacement was presented by Joy et al. (1974) - a vertical line through the center of the tibia, which should also pass through the center of the talus, was used as a measure of talar shift. Similarly, in the lateral view, this line should pass through the most superior part of the talar dome. Also, in the a-p view the distance between the talar surface and the tibial surface at the medial and lateral edges of the talus should be equal to within ± 0.5 mm - otherwise there is a talar tilt.

Strict requirements for a good reduction were also laid down by Weber (1972) - no deviations whatsoever from the anatomical position should be tolerated. The rating of reduction is, however, in the scoring system combined with an evaluation of arthrosis, and therefore a poor result may occur in a perfectly reduced ankle. Again, with this combined scoring, an ankle with minor displacement, but free of arthrosis will be classified as poor, downgrading the results in conservatively treated patients (Phillips & Spiegel 1979).

Sarkisian & Cody (1976) use the talo-crural angle, the angle between a line between the tips of the malleoli, and a line parallel to the tibia surface in an a-p view with internal rotation (the mortise view). They propose that rotation of the fibula leads to considerable shortening and therefore to a change of the talo-crural angle. In a review of 150 cases followed for more than one year they found a relationship between results and talo-crural angle. Similarly, Phillips et al. (1985) found that the talo-crural angle was the best predictor of end result. Goergen et al. (1977) reviewed these methods and found that there is no substitute for an accurately positioned (15-20 degrees of internal rotation) antero-posterior radiogram of the ankle.

Lindsjö (1981) found that 20 per cent of ankles classified by the

surgeon as perfectly reduced, were in fact not, when scrutinized by an independent examiner.

In our prospective randomized controlled series (III) we used the apparatus described by Bohlin (1961) to obtain adequate radiograms. Displacements have been assessed by experienced radiologists, who had no other information on the patients. The combined grading system of Cedell (1967) was applied only after each component of the injury had been estimated separately.

Residual displacement and final results

Most authors believe in a correlation between the degree of reduction and the final result (Magnusson 1944, Palmer 1944, Bonnin 1950, Baek Kristensen 1953, Böhler 1957, Vasli 1957, Jergesen 1959, Braunstein & Wade 1959, Willenegger 1961, Burwell & Charnley 1965, Wade & Lance 1965, Cedell 1967, Malka & Taillard 1969, Weber 1972, Brodie & Denham 1974, Svend-Hansen et al. 1978, Phillips & Spiegel 1979, Joz-Roland et al. 1980, Lindsjö 1981, Zenker & Nerlich 1982, Tunturi et al. 1983, Leeds & Ehrlich 1984 and Olerud & Molander 1984). The data of our studies (III, IV) do not contradict this concept. However, there is some evidence that this is not the only or perhaps not even the most important factor. In spite of all these data the distinction between acceptable and unacceptable reduction remains unclear (Hamilton 1984).

The importance of the medial malleolus

For many years the major importance for the stability of the ankle was attributed to the medial structures (Ashurst & Bromer 1922). Consequently, if conservative treatment failed to achieve correct reduction on the medial side of the ankle, open reduction and internal fixation was advised. The lateral malleolar fracture could then be manipulated and held in position in a cast (Müller 1945, McLaughlin & Ryder 1949, Braunstein & Wade 1959). Only rarely was it felt to be necessary to operate on a fractured lateral malleolus (Cox & Laxson 1952, Joy et al. 1974).

An indication for operation was also a fracture of the medial malleolus at the level of the tibial plafond, since it was assumed

that a possible fibrous union here would lead to talar instability (Wilson & Skilbred 1966).

In recent years a consequence of the tendency of primary repair and anatomical reduction of the lateral side of the ankle has been internal fixation also of the medial malleolus in order to attain stability (Weber 1972, Lindsjö 1981). Further, medial malleolar dislocation compromising the sensitive skin in this area, displacements which cannot be adequately reduced by closed means, and fractures of the medial malleolus with intra-articular fragments are usually operated on (Hughes 1980).

Whether deltoid ligament tears must be sutured is debated. Müller et al. (1963), Cedell (1967), Weber (1972) and Burri et al. (1978) suggest suture of the deltoid ligament in all instances, whereas Heim (1973), who primarily sutured all cases of ruptured medial ligaments, has later taken a more gentle approach. In cases with restored lateral stability, a perfectly reduced and stable medial side, and no interposition, suture of the deltoid ligament is not necessary since the medial aspect of the ankle is stabilized by the tibialis anterior and tibialis posterior muscles (Heim 1978). Both Heim (1983) and Burri et al. (1978) allow immediate functional treatment - early active movements without weight-bearing in patients with a deltoid ligament tear, provided the other injured structures of the ankle are appropriately secured.

The importance of the lateral malleolus

Lauge-Hansen (1942), Danis (1949), Weber (1966) and Olerud & Johansson (1967) focused their interest on the lateral side of the joint.

Breitenfelder (1957) in autopsy experiments demonstrated that a dorsal displacement of the lateral malleolus changed the longitudinal axis of the talus by 10° and thought that this would produce arthrosis. Willenegger (1961) proposed that such biomechanical considerations could explain arthrosis following ankle fractures better than the hypothesis of primary injury to the articular cartilage. An exact reduction and maintenance of the

stability until healing, was the only guarantee for a satisfactory end-result (Willenegger & Weber 1965). In later experiments the Willenegger group pointed out the importance of correct length and position of the lateral malleolus. A lateral displacement of 1-2 mm was enough to reduce the tibio-talar contact area by 30-60 per cent - the reduction is most marked in the postero-lateral part of the tibio-talar articulation (Riede et al. 1969, 1971a) There were large individual variations due to differences in the talar profile because of age, or variations in the normal anatomy (Riede et al. 1971b, 1973, Riede & Hehne 1978).

From studies of the cellular composition of the cartilage, and in combination with the factors above, Riede & Hehne (1978) concluded that already from age 30 on, the inherent compensation mechanism will be insufficient, and any incongruence in the joint will eventually lead to arthrosis.

Ramsay & Hamilton (1976) in similar experiments confirmed the drastic reduction in the tibio-talar contact area by a lateral displacement of the distal end of the fibula, with the greatest reduction - 42 per cent - occurring in the first mm of lateral shift.

These findings have their counterpart in the clinical literature. A residual displacement of the lateral malleolus or a lateral talar shift, has been correlated with poor end results by many authors (Magnusson 1944, Kleiger 1961, Wilson & Skilbred 1966, Solonen & Lauttamus 1968, Brodie & Denham 1974, Joy et al. 1974). In a much cited paper Yablon et al. (1977) claimed that the lateral malleolus has the key role in displaced ankle fractures and demonstrated in an experimental series on autopsy specimens, how dividing the deltoid ligament or fracturing the medial malleolus did not create any instability of importance, whereas resection of the distal end of the fibula did (Yablon et al. 1977). In a clinical series of 53 patients the authors then reported excellent results following accurate anatomical reduction and fixation of the fibula fracture with a four-hole plate.

Martinek & Egkher (1978) and Mitchell et al. (1979) issued special warnings against a shortening of the fibula, and pointed out that this is difficult to overcome by closed reduction only. After successful closed treatment the fibula is held in place by increased tension in the lateral ligaments causing non-physiological load on the lateral part of the tibio-talar joint, and thus leading to arthrosis in spite of radiographically good or even perfect reduction.

Püschel (1974), however, found that minor rotational displacements were well tolerated, and Zifko (1968) that a lateral displacement of the lateral malleolus of up to $1/3$ of its width was well tolerated in cases otherwise anatomically reduced.

The importance of the posterior tibia margin

Posterior tibia margin fractures usually occur together with fractures of the medial or lateral malleoli in any of the fracture producing mechanisms described by Lauge-Hansen (1942) and the different types according to Weber (1966). When produced by an external rotation trauma or by abduction the injury is usually postero-lateral, in SA II or Weber type A fractures it is usually postero-medial. Henderson (1932) invented the expression "tri-malleolar fracture" for the large joint surface bearing fragment; today this expression also includes minor extra-capsular posterior tibia margin avulsions (Hamilton 1984).

A fracture of the posterior tibia margin can occur as an isolated injury (Frank 1941, Hendelberg 1943, Yde 1980, Lindsjö 1981, Buschmeyer & Moschinski 1984) - 0.8 - 2.8 per cent of ankle fractures. Broström et al. (1964) found isolated posterior tibia margin fractures to be associated with tears of the anterior-inferior tibio-fibular ligament and Hamilton (1984) from studies of the literature, concluded that these fractures could not occur without associated soft tissue injury.

The presence or absence of a posterior tibia fragment has been assigned great prognostic importance - when there is a posterior fragment, the prognosis is worse (Felsenreich 1937, Magnusson

1945b, Graff 1954, Willenegger 1961, Klossner 1962, Henke 1964, Cedell 1967, Tauber et al. 1971, McDaniel & Wilson 1977, Nonnemann & Bräutigam 1977, Lindsjö 1981, Zenker & Nerlich 1982). Niethard & Plaue (1977) held the same view, but remarked that this is due to the sequence of events. The posterior injury represents a more extensive injury, which is also reflected by the Lauge-Hansen stages. They also found that even the smallest flake fragment doubled the rate of post-traumatic arthrosis. Fischer & Brändle (1982) came to the same conclusion, the number of lesions were more important than the quality of reduction - unimalleolar fractures never had poor results. In the prospective randomized controlled study (III) there was further support for the relationship between arthrosis and extensive fractures.

The treatment suggested has depended on the size of the fragments. There is general agreement that "large" fragments should be adequately reduced. "Large" may be fragments carrying more than $1/5$ of the joint surface (Reimers 1953, Terbrüggen & Willenegger 1973, Niethard & Plaue 1977), more than $1/4$ of the surface (Klossner 1962, Neufeld 1965, Cedell 1967, Decker 1977, McDaniel & Wilson 1977, Yablon & Segal 1983) or more than $1/3$ of the surface (Cox & Laxson 1952, Braunstein & Wade 1959, Burwell & Charnley 1965, Harrold 1972, Maatz & Nonnemann 1973, Eventov et al. 1978).

The size of the fragment can, however, be difficult to estimate from the radiogram (Hendelberg 1943) and is frequently larger than expected (McDaniel & Wilson 1977, Heim 1982). Tauber et al. (1971) noted that fragments less than $1/4$ of the surface were well tolerated provided the talus was in its correct position, whereas fragments including more than $1/3$ of the surface always resulted in arthrosis. A small diastasis was found to be of no importance.

Although the posterior fragment tends to become reduced with the malleoli, since the posterior ligaments are usually intact (Decker 1977), closed treatment was often unsuccessful and skeletal traction has been suggested for these fractures (Dickson 1933, Nyström 1944, Böhler 1957), although Felsenreich (1931) suggested percutaneous pinning.

Today's treatment usually consists of screw fixation (Vasli 1957, Cedell 1967, Weber 1972, Müller et al. 1978, Lindsjö 1981, Heim 1982) but the use of special plates has been proposed (Miller 1974).

However, even after anatomical reduction a large posterior fragment is associated with a high risk of arthrosis (Lindsjö 1981). The data of the present studies (III) and (IV) confirm these findings, the presence and to some extent the size and displacement are of importance for the production of arthrosis. However, as also pointed out by Niethard & Plaue (1977), these variables are closely related to the severity of the injury and to the causing trauma.

Pseudarthrosis of the medial malleolus

Conservative treatment of ankle fractures results in high rates of non-union of the medial malleolus - 5 - 20 per cent (Magnusson 1945a, Baek Kristensen 1949, Biström 1952, Burmeister 1963, Stören 1964, Wilson & Skilbred 1966). The inter-position of soft tissues, residual diastasis or persistent instability in the cast, have been suggested as causes (Lee & Horan 1943, Biström 1952, Reimers 1953, Klossner 1962, Mendelsohn 1965).

In comparisons between conservative and operative treatment of ankle fractures Vasli (1957), Klossner (1962) and Malka & Taillard (1969) found fewer pseudarthroses after open operative treatment than after closed reduction. Stören (1964) holds the view that pseudarthrosis of the medial malleolus is of little clinical importance. He is supported by Weber (1972).

Mendelsohn (1965) and Sneppen (1971b) proposed that a medial malleolar pseudarthrosis does not influence the long term prognosis of a fractured ankle, whereas Cox & Laxson (1952) thought that pseudarthrosis would dispose for arthrosis.

In the randomized prospective study (III) there were no cases of pseudarthrosis in either group. In the 30 year follow-up (IV) two cases with medial malleolar pseudarthrosis were encountered, both

in women with supination-eversion fractures, stage IV. Both cases had been left with a persistent diastasis of the medial malleolar fracture of 2 mm. Both had moderate symptoms, and one developed arthrosis. In these cases, the gap was not bridged by bone even after 30 years, although Sneppen (1970) found spontaneous healing with time in about 1/3 of 117 cases.

Pseudarthrosis of the lateral malleolus seems to be a rare complication compared with the medial side - 0.1 per cent of lateral malleolar fractures (Sneppen 1971a). Mendelsohn (1965) thought that it is most frequent in displaced transverse fractures of the supination adduction type.

No case with pseudarthrosis of the lateral malleolus was encountered in our series (III, IV).

Arthrosis of the ankle in relation to other joints of the lower extremity

Primary arthrosis of the ankle is extremely rare if it exists at all (Funk 1976, Stauffer et al. 1977, Resnick & Niwayama 1984). In fact Meachim (1975) thinks an additional factor such as trauma, neuropathy or rheumatoid disease is necessary to induce clinical arthrosis. This puts the ankle in a unique position vis-a-vis the other weight-bearing joints of the lower limb. In the hip and the knee there is a prevalence of primary arthrosis of a few per cent (Danielsson 1964, Danielsson & Hernborg 1970, Jörring 1980, Lindberg 1985). Post-traumatic arthrosis has been reported to occur in 12 - 26 per cent after acetabular fractures (Rowe & Lowell 1961, Letournel 1980). After fractures of the patella Boström (1972) found 22 per cent patello-femoral arthrosis and Rasmussen (1971) found 21 per cent arthrosis after tibia condylar fractures. Estimates of post-traumatic arthrosis after calcaneus fractures are less exact - Thorén (1964) found subtalar arthrosis in 2/3, based on the presence of osteophytes only. Widén (1954) stated that although osteophytes are often seen, the true frequency of arthrosis after calcaneus fractures cannot be estimated and Tanke (1982) in his extensive review of the literature presented no frequencies.

Even if primary ankle arthrosis is rare, arthrosis is equally common in ankle fractures as in other intra-articular fractures of the lower limb (Table 2) - the difference being that the cases hardly ever present themselves with symptoms (IV) - only follow-up will reveal these cases. Whereas arthrosis of the hip and the knee is usually progressive (Danielsson 1964, Hernborg & Nilsson 1977) ankle arthrosis is usually not - minor changes do not necessarily progress to a disabling condition, as suggested by the 30 year follow-up (IV).

Arthrosis producing factors

Radin et al. (1972) suggested that the ankle joint which has a large contact area relative to its load should rarely develop arthrosis. When this area becomes smaller following fracture with displacement of the malleoli and reduced tibio-talar contact area (Riede et al. 1969, Ramsay & Hamilton 1976) arthrosis will develop (Riede & Hehne (1978)). The question is whether this is an "all or nothing" phenomenon or whether there is a tolerance level which may not be exceeded.

Most recommendations regarding operative treatment for even minor displacement are based on the experimental works of Riede et al. (1969, 1971 a and b, 1973) and by Ramsay & Hamilton (1976). These authors state that a fibular displacement and a talar shift of a certain degree leads to less tibio-talar contact area and increased risk of arthrosis. In many cases, probably, as in the SE II-fractures, the talus remains well contained in its normal position in the ankle mortise. From the experiments of Close (1956), Grath (1960), Phillips et al (1969) and Pankowich & Shivaram (1979) we know that, with an intact deltoid ligament, the talus will stay in the mortise and that a rupture of the ligament must occur if the talus is displaced > 2 mm. Although the reduction in the tibio-talar contact area is most pronounced for the first millimeter or for the first degree of displacement this may still be tolerated. It is evident that minor deviations from the normal anatomical position are well tolerated and do not necessarily lead to arthrosis, not even after a long time, as evidenced by the SE II-fractures in the 30-year perspective (IV).

Furthermore, the severity of the injury, sex and age also seem to explain part of the variance in arthrosis occurrence (III, IV).

The tendency to develop post-traumatic arthrosis may, however, also be constitutionally inherent in the individual (Doherty et al. 1983). This would be an additional explanation to the large residual variance in the injury - treatment - arthrosis relationship.

Conservative vs operative treatment of ankle fractures

Most of the numerous studies in the past concerning various types of treatment of ankle fractures do not permit any conclusions whatsoever about the difference between a more conservative and a more radical approach, open or closed reduction, extensive or less extensive osteosynthesis. This is because of differences in the criteria of classification and methods of evaluation. In conservatively treated patients the occurrence of arthrosis ranges from 33 - 86 per cent and with internal fixation from 7 - 70 per cent (Table 2). Any attempt to compare the functional results between most of these studies either within the groups conservative and operative treatment or between the groups would be even less successful (Phillips & Spiegel 1979). However, some attempts have been made to produce data for comparison between various types of treatment - uniform or similar classifications and protocols have been applied:

Non-operative treatment of ankle fractures were found to yield the best results in studies by Trojan & Jahna (1965), Eventov et al. (1978) and Schouwenaars & Mulier (1979). In these studies it appears that conservative treatment was, as a general rule, tried first and open treatment performed either in the more severe fractures and/or after failed conservative treatment. In retrospective studies other authors found no major differences in the outcome of the two treatment principles (Kett et al. 1965, Wilson & Skilbred 1966, Joy et al. 1974, Wheelhouse & Rosenthal 1980, Joz-Roland et al. 1980). Again the selection criteria were not well defined.

Table 2. Frequencies of post-traumatic arthrosis (%).

	Cons	Op
Magnusson 1944	49	
Vasli 1957		43
Klossner 1962	38	40
Burmeister 1963	67	
Stören 1964	39	
Kroupa et al. 1965	86	
Kett et al. 1965	56	60
Burwell & Charnley 1965		37
Wilson & Skilbred 1966	33	46
Leitz 1966	64	15
Cedell 1967		23
Martinez et al. 1970		32
Tauber et al. 1971	59	
Müller et al. 1971		27
Weber 1972		7
Luhnau 1972		16
Brodie & Denham 1974		9
Pankarter 1977		12
Schweiberer & Seiler 1978		23
Schouwenaars & Mulier 1979	50	
Yde & Kristensen 1980b	66	20
Joz-Roland et al. 1980	37	34
Lindsjö 1981		14
Muschter and Scholz 1982	58	12
Lange et al. 1984		70
Phillips et al. 1985	69	69
Present study III	65	72
Present study IV	18	

Even if better reduction is usually attained by operation, there is no difference in the outcome of cases with adequate reduction regardless of method (Klossner 1962, Vécsei et al. 1982, Beauchamp et al. (1983).

In one of the best comparative studies Yde & Kristensen (1980a) had

excellent end-results in SE II fractures for both operative and conservative treatment - the latter group put in a cast without even an attempt at reduction. The authors proposed that operation was not needed in this type of fracture, but pointed out that the follow-up - 3 - 10 years - was short, but Kristensen & Hansen (1985) had similar results also after 21 years.

However, most comparative studies seem to be in favour of operation. Malka & Taillard (1969) had better reduction after open treatment, but presented no long term results. Solonen & Lauttamus (1965) concluded the same in spite of more arthrosis in their operated patients. Historical controls were used by Leitz (1966), Martinez et al. (1970), Willenegger (1971), Müller et al. (1971) and Muschter & Scholtz (1982) and data collected by other authors by Vasli (1957) and Cedell (1967). Hughes (1979) and Yde & Kristensen (1980 a,b) compared hospitals with different treatment policies. Also operations only after failed conservative treatment have been reported, with results better than the conservative treatment (Braunstein & Wade 1959, Gay & Evrard 1963, Lecestre & Ramadier 1976). Pettrone et al. (1983) found in a study on displaced ankle fractures, open reduction - stabilizing all fragments - to be better than closed.

The unfortunate lack of randomized controlled studies makes all these data circumstantial evidence only. Phillips et al. (1985), however, presented a study with a secondary randomization procedure - only cases successfully reduced were randomized to closed or open treatment. There was no difference in the outcome except for a better position in the operated patients.

Thus it is not proven that operative treatment is superior to conservative (Phillips & Spiegel 1979) and even less what type of operation is the best.

The debate of this question has at times taken the proportions of a religious war (van der Ghinst et al. 1977). However, Wade & Lance (1965) suggested that "the two methods are not mutually exclusive, but mutually complimentary".

The data of our studies (III, IV) suggest that at least one common type of ankle fracture - SE II - will do well without surgery. This is supported by the findings of Kristensen & Hansen (1985) who reviewed conservatively treated SE II fractures after 21 years and found good subjective results and no arthrosis. Also, Cedell (1985) now advocates closed treatment of SE II fractures, possibly with the exception of those with ligament avulsion fractures.

The change in sex and age specific incidence towards the pattern of fragility fracture (V) may also leave some leeway to alternative methods, particularly if the quality of bone does not permit stable osteosynthesis.

SUMMARY AND CONCLUSION

From initial studies of measurements from repeated roentgen examinations in the same individual and from reviewing roentgenograms in healthy individuals it could be concluded that differences in joint space of the ankle is studied just as well in films of non-weight bearing as in films of weight bearing ankles and that the joint space does not change with age in adult man.

In a study of 92 cases of ankle fracture (Weber type B) which had been randomized to closed reduction and plaster cast fixation or open reduction and osteosynthesis with the AO-method and which were also available for follow-up, the function and the occurrence of arthrosis were compared on two occasions:

Operative treatment of type B fractures resulted in better reduction, more rapid decrease in swelling and more rapid gain of motion than closed reduction. Some fractures could not be adequately reduced by closed methods alone.

The initially more favourable restoration after operative treatment did not prevail.

In spite of the better reduction, arthrosis developed also in operated cases and could occur also in ankles that had been reduced to an exact position, whereas many joints with a poor fracture position were free from arthrosis. Seven years after the injury pain and discomfort were present in about 1/3, with both types of treatment.

The relatively poor relationship between reduction and arthrosis suggests interaction of factors other than treatment - particularly the degree of skeletal involvement.

The Weber classification which does not take into account the degree of skeletal involvement is probably not suitable for stratification in clinical trials unless the number of observations is sufficient to exclude the possibility of spurious differences.

In a study of 143 conservatively treated ankle fractures which were subjected to clinical and roentgen examinations after an average of 29 years it was observed that:

Over 80 per cent of the patients were completely free of symptoms and over 80 per cent had no roentgenological signs of arthrosis. The arthrosis changes were usually of a moderate degree and only in the worst cases closely related to clinical symptoms. Only a few patients had sought medical advice over the years for symptoms following their ankle fracture.

Arthrosis was more common in the initially more severe fractures.

The most common ankle fracture, supination-eversion stage II, had minimal signs of arthrosis in one patient only. Displacement of the lateral malleolus of up to 2 - 3 mm did not cause arthrosis. Supination-eversion stage IV-fractures caused subjective symptoms and arthrosis but almost only in women.

The concept that all ankle fractures must be perfectly reduced

is not supported by the findings in the isolated lateral malleolar fractures, since they hardly presented any problems at all.

Slight radiographic changes may simply be signs of a previous injury and not necessarily a proof of degenerative joint disease.

In an additional study the sex and age specific incidence was calculated for fractures from the first part of the 1950's and compared with the 1980's - a 30 year interval. During that time interval ankle fractures had become more common, particularly those with extensive skeletal involvement, such as the stage IV supination-eversion fractures, which today have an incidence pattern more typical of a fragility fracture in old women.

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APPENDIX

APPENDIX

Analysis of ankle joint space measurements

It was considered to be of interest to compare joint space measurements obtained from three sets of data: the normal controls (II), the fractured and non-fractured ankles on films of the late follow-up of the prospective series (III) and the fractured and non-fractured sides in the 30-year follow-up study (IV). The method of measurement is described in (II). The measurements of (II) and (IV) were carried out by one radiologist (KJ) whereas the measurements in (III) were performed by another (BB), both using the method described in (II).

The outcome of these comparisons is demonstrated in Figure (App:1).

The fracture cases (III and IV) were compared with the controls (II) and the joint space measurements were also related to age. There was a considerable deviation from "normal", partly due to the presence of a limited number of arthrosis cases, but also in those patients whose measurements are still within the normal limits there is a tendency of clustering in the lower part of the distribution.

Comments

The difference between fractured and non-fractured ankles was rather small and only due to the presence of a limited number of patients with arthrosis. More remarkable and unexpected was the deviation of both the fractured and the non-fractured sides of the fractured patients from the data of the normal controls. The first explanation may be a systemic error in the method in spite of the fact that those data that were produced by the same investigator differed the most, i.e. the normal controls and the 30-year follow-up study (II, IV). We are left with the possibility that the joint space in patients with ankle fractures is slightly reduced, not only in the injured ankle but also in the un-injured one, after an average of 30 years.

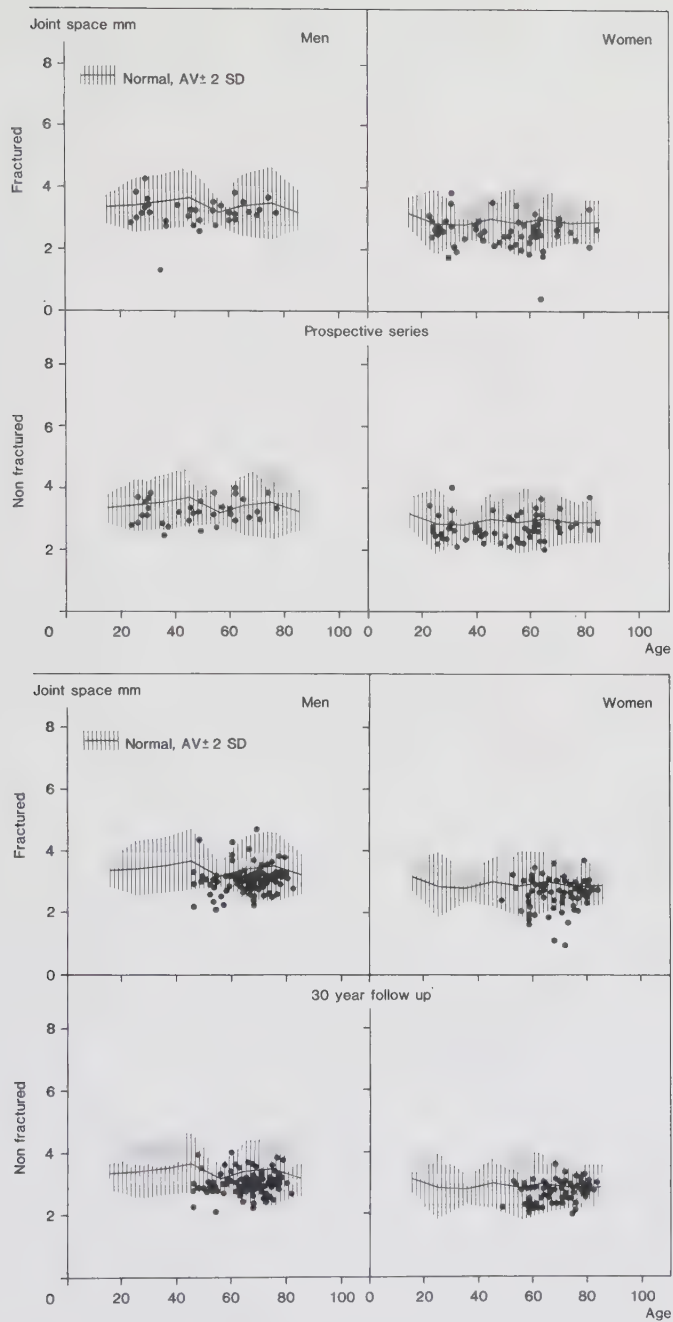


Figure App:1. Measurements of ankle joint space in patients with ankle fracture compared with controls without fracture (shaded). Fractured and non-fractured ankles in the randomized prospective (upper) and the 30-year follow up study (lower).

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